MARCH 1959

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ILLUMINATING ENGINEERING

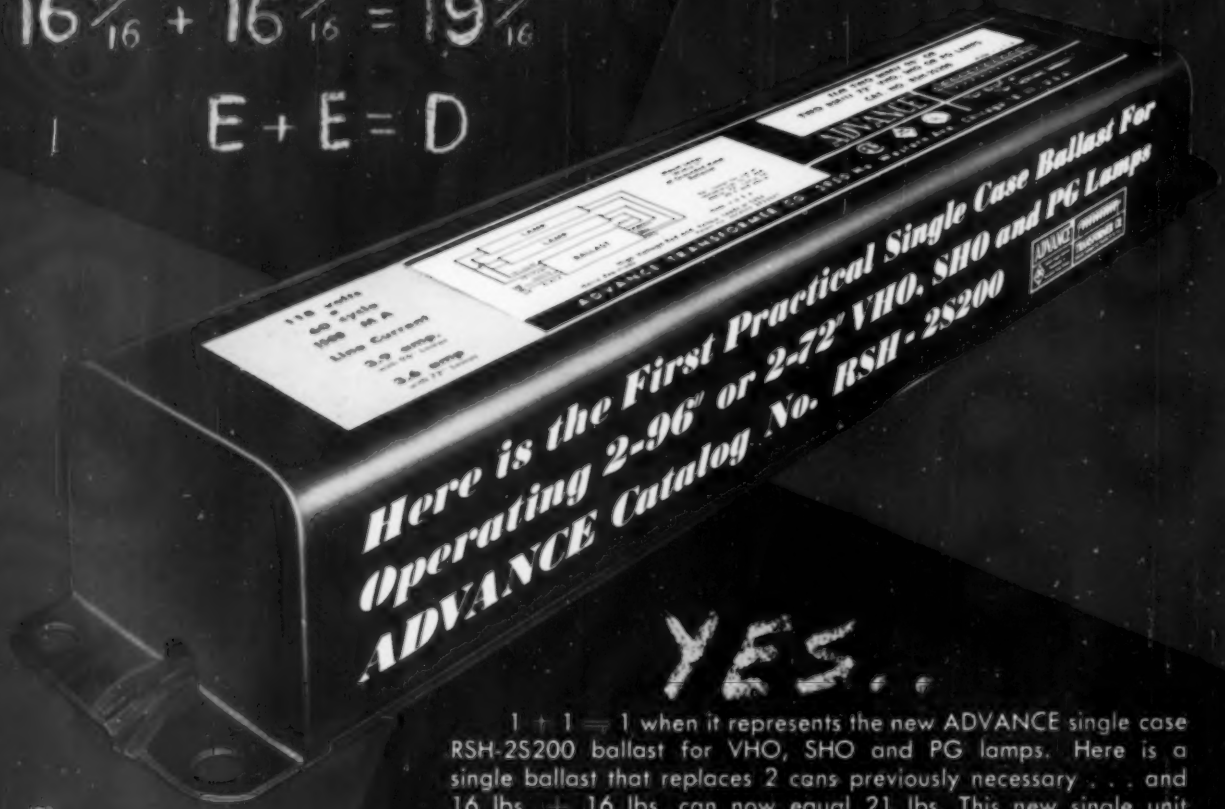
Journal of the
ILLUMINATING ENGINEERING SOCIETY

NOW 1 + 1 = 1

16 lbs + 16 lbs = 21 lbs

$16\frac{11}{16}'' + 16\frac{11}{16} = 19\frac{3}{16}''$

E + E = D



Here is the First Practical Single Case Ballast For Operating 2-96" or 2-72" VHO, SHO and PG Lamps ADVANCE Catalog No. RSH-2S200

YES...

1 + 1 = 1 when it represents the new ADVANCE single case RSH-2S200 ballast for VHO, SHO and PG lamps. Here is a single ballast that replaces 2 cans previously necessary . . . and 16 lbs. + 16 lbs. can now equal 21 lbs. This new single unit weighs only 21 lbs., a saving of 11 lbs. over 2 case installations.

16-11/16" + 16-11/16" = 19-3/16". Where two ballasts formerly required almost 3 ft. of channel this new ADVANCE single case unit saves space as it is only 19-3/16" long . . . installing one ballast in place of two cuts labor costs in half.

Then too, E + E = D. ADVANCE engineers have designed this single ballast to operate at a lower sound rating level. Now in place of 2 ballasts of E sound ratings, the new ADVANCE RSH-2S200 ballast is sound rated D. This makes it possible to use VHO, SHO and PG lamps in places where heretofore these installations were unsatisfactory because of ballast noise.

The ultimate service of a ballast depends on its design, construction and operation at low temperature. ADVANCE now brings you a single case ballast for operating two—96" or two—72" VHO, SHO, or PG lamps incorporating these principles. There is no finer ballast . . . none that will operate cooler or longer. Write today for complete technical data.

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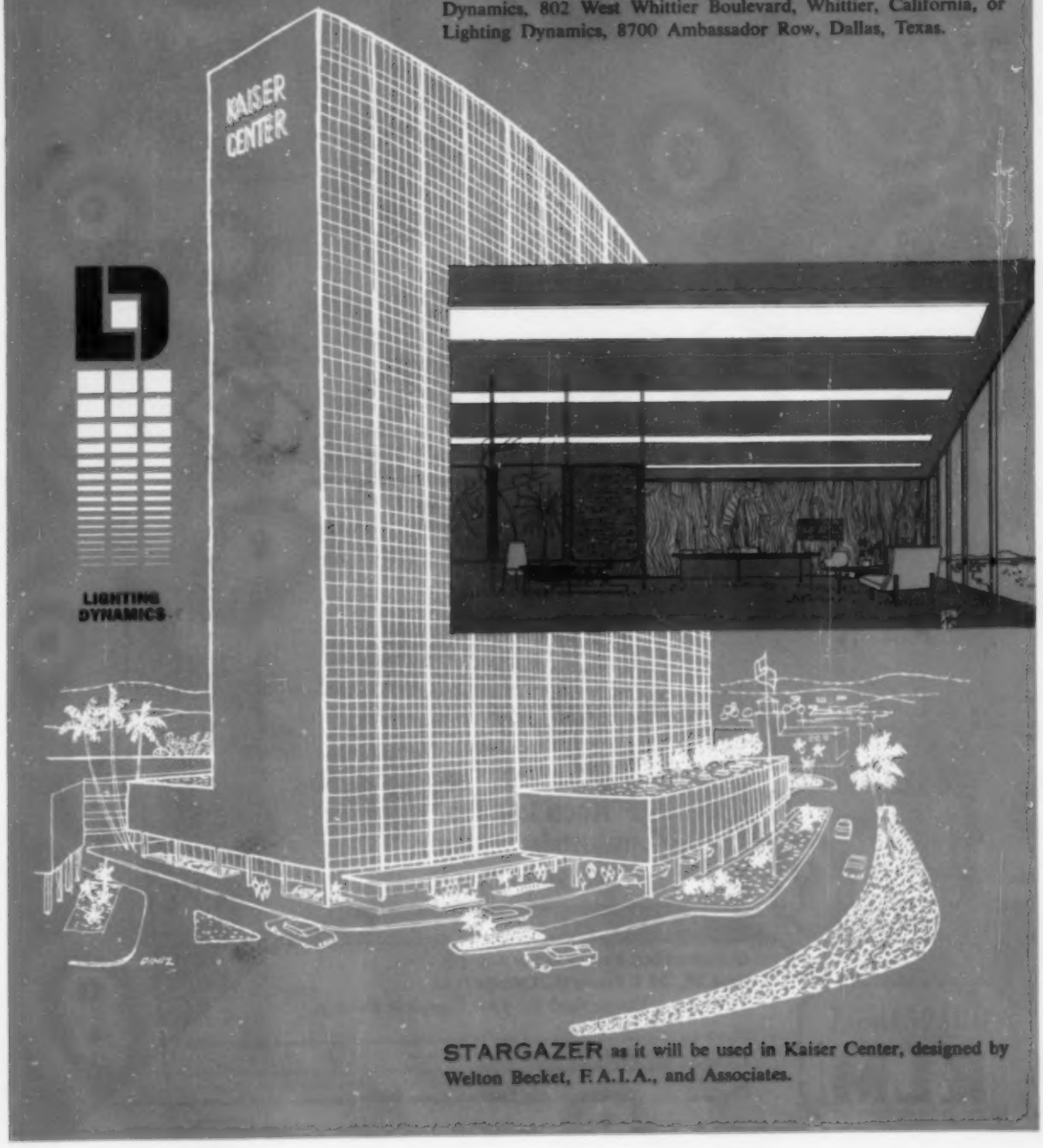

STARGAZER as it will be used in Kaiser Center, designed by Welton Becket, F.A.I.A., and Associates.

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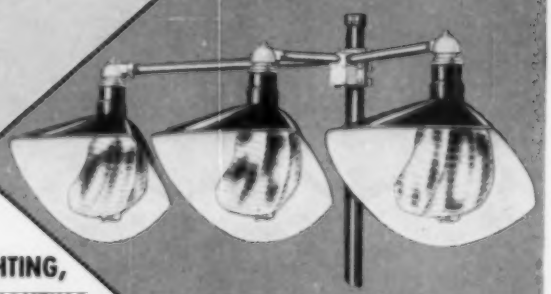

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THE JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

March
1959

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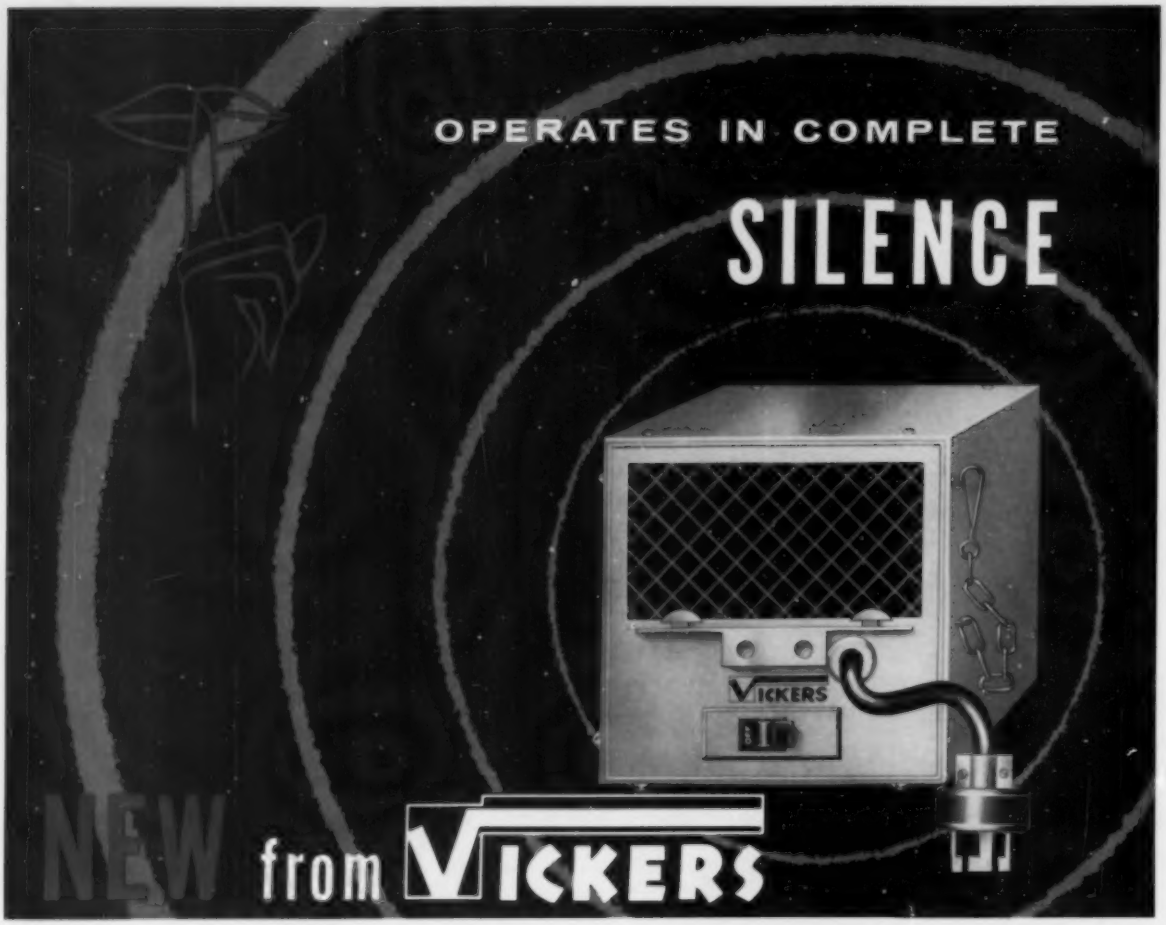

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dimmer units only 5" cube (5 lbs.)...mount right at the light source

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Filling a long-felt need in the field of theatrical lighting control, these new Vickers dimmer units have gained quick acceptance—more than 400 will be installed throughout the country by September, 1959.

Bulletin 5426-1 contains complete information about the Vickers Mark II lighting control system incorporating Silicon Controlled Rectifier dimmer units. Write for your copy today.

EPA 5400-2

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NEW SMITHCRAFT LARGE ELEMENT
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This completely new office building of the Walworth Company, leading valve manufacturer, uses Litecontrol fixtures throughout, except for a few small areas.

The Conference Room, a handsome interior, received special treatment. Litecontrol strip fixtures were specified behind a mahogany valance around the four sides. They illuminate the walls and part of the ceiling. The center bay of our lens fixtures illuminates the conference table. All of these latter fixtures may be operated together, or half of them, as desired.

The same fixtures used in the office were also utilized, spread out, in the Cafeteria and in the washrooms which indicates the versatility of the equipment. The employees who have to live with the lighting speak very highly of it — *especially of its comfort*. After working all day, there are no late afternoon headaches. The lighting intensity is evident but glare is absent.

Litecontrol is a good name to remember when commercial lighting is under discussion. *It does the job. It cuts your costs.*

INSTALLATION:
Walworth Company,
South Braintree, Mass.

AREA SHOWN:
Conference Room

ENGINEERS:
Charles T. Main, Inc.,
Boston, Massachusetts

ELECTRICAL CONTRACTOR:
Hixon Electric Company,
South Boston, Mass.

GENERAL CONTRACTOR:
George A. Fuller, Co.,
Boston, Massachusetts

GENERAL OFFICES:
Ceiling Height 9′ — 0″
Fixture spacing, 7′ — 0″
on centers
Fixtures, Litecontrol
#6828SL-70 two lamp
slimline, with Corning
Pattern 70 lens panels,
grid ceiling fixtures.
Average intensity,
85 footcandles in service.

CONFERENCE ROOM:
Ceiling Height 9′ — 2″
Fixtures, Over table,
Litecontrol #8424RS,
two lamp rapid start,
with Holophane #6025
acrylic CONTROLENS*
#N-15SC-48DRS rapid
start strip fixtures
behind valance.
Average intensity, on
table, 200 footcandles
in service.
*Reg. Holophane Co., Inc.

LITECONTROL
Fixtures
KEEP UPKEEP DOWN
LITECONTROL CORPORATION,
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DESIGNERS, ENGINEERS AND MANUFACTURERS OF FLUORESCENT LIGHTING EQUIPMENT DISTRIBUTED ONLY THROUGH ACCREDITED WHOLESALERS

Planning Location of Luminaires

In the past, many engineers, architects and contractors planned lighting layouts without the use of the lumen formula method. Now, with the new higher recommended levels and higher-output lamps, it becomes increasingly necessary to use the lumen method for predetermining intensities. Often, however, the problem begins after the number of luminaires has been determined, when the engineer is confronted with the job of spacing the fixtures according to manufacturer's spacing-to-mounting height ratios. Many lighting textbooks leave this to the experience of the designer, thus handicapping the less-experienced engineer who must resort to a trial and error method. This, of course, is time-consuming and frustrating, results in discouragement with the lumen method and poorly planned lighting layouts. Here, to help in simplifying this operation, for the novice as well as the experienced engineer, is a simple, four-step method of planning location of luminaires.

Prior to planning spacing, six specifications must be determined: level of illumination, system and luminaires, coefficient of utilization, maintenance factor, number of lamps and luminaires and recommended spacing of selected luminaires. The last, of course, provides invaluable assistance in determining *how* and *where* the luminaires should be placed in the room.

Manufacturers' literature usually contains distribution information for the fixture type selected. Generally, the maximum spacing to mounting height ratio is not greater than one-to-one for direct-indirect, semi-direct and general diffuse luminaires. Recessed or direct and semi-direct luminaires are often spaced on less than this one-to-one ratio, and spacing for a concentrating type of high-bay fixture should not exceed .5 of the mounting height, or .8 for medium distribution. Since good distribution is so essential to a quality lighting system, it is often desirable to plan closer spacing than the maximum recommended by the manufacturer.

With the aid of the following examples, in which the first five specifications have been completed, the "four-step" method for determining the sixth specification, luminaire spacing, can be illustrated.

Drawings and data courtesy of James F. Finn, Detroit Edison Co., Detroit, Mich.

Problem I: To provide 100 footcandles of general lighting for an office 34 feet wide and 58 feet long; ceiling height, 11 feet. An eight-foot direct-indirect two-lamp luminaire using 96T12 800 ma cool white lamps and having 45- by 45-degree shielding has been selected. Manufacturer's literature recommends a maximum spacing to mounting height ratio of one-to-one. With the luminaires suspended 1 foot 6 inches from the ceiling, the mounting height is 9 feet 6 inches, and therefore, the maximum spacing between luminaires should not exceed 9 feet 6 inches on centers.

From specification five (number of lamps and luminaires) it has been determined that 30+ luminaires are required for this area. Spacing of luminaires can be quickly and easily established by following these four basic steps.

Step 1. *Establish distance from walls to first row of luminaires.**

As shown in Fig. 1, the side rows of luminaires are mounted so that the center line is 2½ feet from the side walls and the ends of the continuous rows of luminaires are 1 foot from the end walls.

Step 2. *Deduct both side wall rows of luminaires from total number of luminaires.*

30+ luminaires (total)
−14 luminaires (2 side rows)

16 luminaires (balance)

Step 3. *Divide the number of luminaires per row into balance remaining to determine number of rows.*

$$\frac{\text{16 luminaires (balance)}}{\text{7 luminaires per row}} = 2.3 \text{ rows}$$

Since every row in the installation must be full, it is necessary either to deduct two luminaires from the balance remaining or add five. However, since it is always good practice in office lighting to increase rather than reduce the lighting intensity, and since it was previously determined that 30+ luminaires are necessary to provide the desired 100 footcandles, five luminaires will be added to the remaining 16.

*Note: Current *Recommended Practice for Office Lighting* states that the maximum distance between the center line of the outer row of fixtures and the adjacent wall should not exceed 2½ feet, and that the ends of continuous rows of luminaires should not be more than 2 feet from the wall, with a preferred minimum of 6 inches to 1 foot.

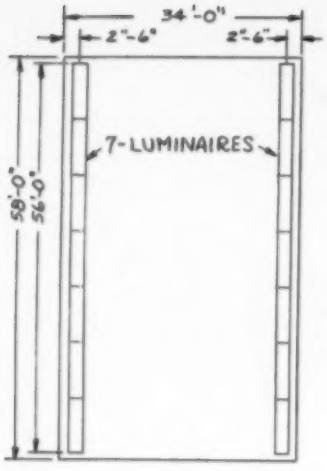


Figure 1. (left). Luminaires in this 34- x 58-foot office are mounted so that center line is 2½ feet from side walls and ends of rows are 1 foot from end walls (Problem I, Step 1).

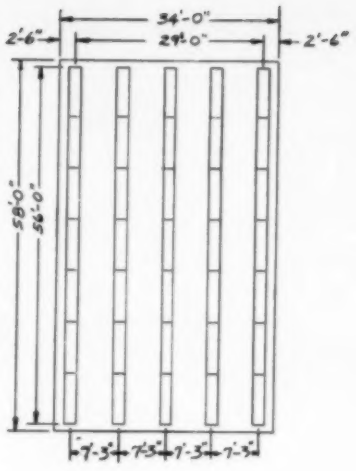


Figure 2. (right). Solution to Problem I: Five continuous rows of luminaires, 7 luminaires per row, mounted on 7-foot 3-inch centers.

$$16 + 5 = \frac{\text{21 luminaires}}{\text{7 luminaires per row}} = \text{3 rows}$$

Step 4. *Divide number of spaces between rows (number of remaining rows plus one integral) into the remaining width of the room, after deducting the total distance between outer rows and side walls. The result will be the width of luminaire spacing on centers between rows.*

34 feet (total width of room)
−5 feet (total side wall spacing)

29 feet (remaining width of room)

$$\frac{\text{29 feet (remaining width)}}{\text{4 (number of rows plus one)}} = \text{7 feet 3 inches spacing between center lines of rows}$$

Solution: Five rows of luminaires, 7 luminaires per row = 35 luminaires producing 112 footcandles (see Fig. 2).

Problem II: To light the same office area as that shown in Problem I (34 by 58 feet, ceiling height, 11 feet), this time, however, with direct-indirect 4-lamp luminaires equipped with 40-watt 48T12 425 ma standard cool white lamps, and having 45- by 45-degree shielding. Manufacturer recommends one-to-one spacing to mounting height ratio for these luminaires.

Assuming that 35 of the above luminaires are required to light this area, the following illustrates the application of the "four-step" method when luminaires are *not* installed in continuous rows.

Step 1. *Establish distance from walls to first row of luminaires.**

Deduct total end wall spacing of luminaires (3 feet on centers at each end — see Fig. 3) from total length of room.

58 feet (total length)
−6 feet (end wall spacing)

52 feet (remaining length)

52 feet (remaining side wall length)

9½ feet (one-to-one spacing to mounting height)

= 5+ or 6 spaces = 5 luminaires spaced 8 feet 8 inches on centers.

Five luminaires spaced between the two end

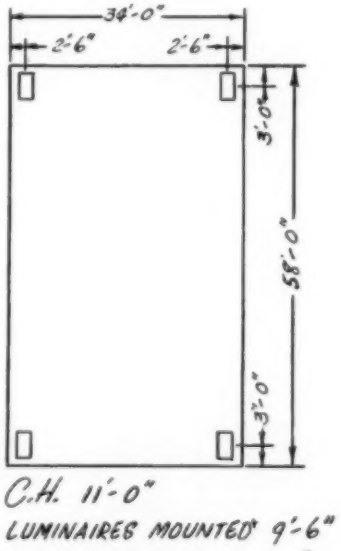


Figure 3. In Problem II, the four end luminaires are mounted three feet, on centers, from the end wall.

*NOTE: *Recommended Practice for Office Lighting* states that, in this case, end wall spacing should not exceed half the distance between luminaires.

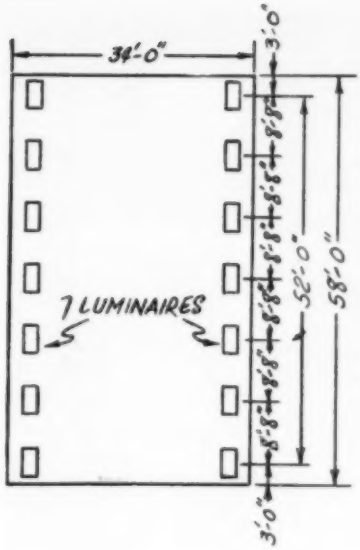


Figure 4. (left). Side rows of luminaires in Problem II are completed when five luminaires spaced on 8-foot 8-inch centers are mounted between two end luminaires in each row.

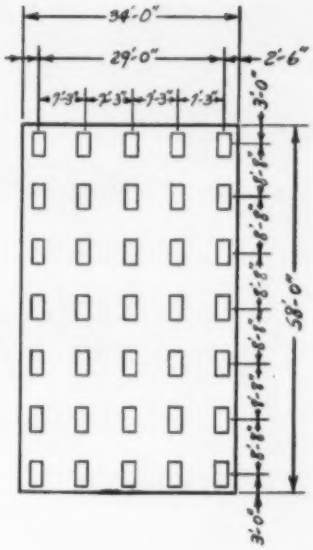


Figure 5. (right). Completed installation for Problem II: Five rows of seven luminaires each, mounted on 7-foot 3-inch centers.

luminaires makes a total of 7 luminaires per row, as shown in Fig. 4.

Step 2. *Deduct both side wall rows of luminaires from total.*

35 luminaires (total)
−14 luminaires (2 side rows)

21 luminaires (balance)

Step 3. *Divide luminaires per row into balance remaining to determine the number of rows.*

$$\frac{\text{21 luminaires (balance)}}{\text{7 luminaires per row}} = \text{3 rows}$$

Step 4. *Divide number of spaces between rows (number of rows remaining plus one integral) into remaining width of room, after deducting total distance between outer rows and side walls. Result will be width of luminaire spacing on centers between rows.*

3 rows + 1 integral = 4 spaces

$$\frac{\text{29 feet (remaining width)}}{\text{4 spaces}} = \text{7-foot 3-inch centers (see Fig. 5).}$$

Problem III: To provide 50 footcandles in a variety store, 60 feet long and 20 feet wide; ceiling height, 11 feet, using eighteen 8-foot luminaires which are equipped with 75-watt T12 425 ma lamps, and having 45- by 35-degree shielding. Mounting

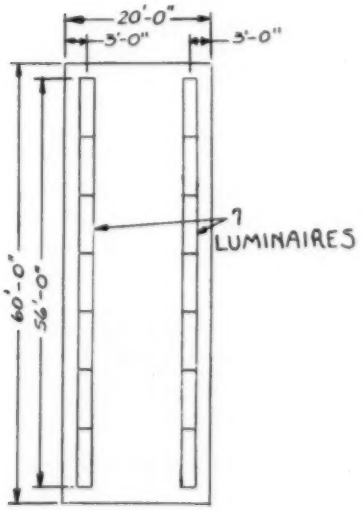


Figure 6. (left). In the Variety Store in Problem III, side rows of fixtures are mounted so that center lines of the continuous rows are 3 feet from side walls.

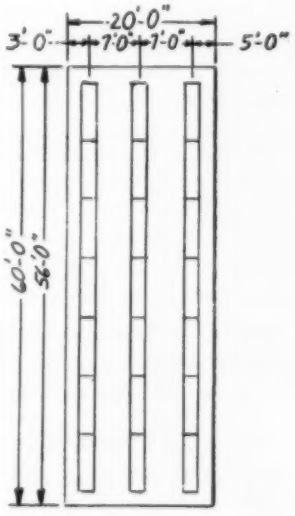


Figure 7. (right). Third row of luminaires in Problem III is mounted so that distance between center lines of rows is 7 feet.

height of luminaires is 10 feet; manufacturer specifies a one-to-one spacing to mounting height ratio.

Step 1. *Establish distance from walls to first row of luminaires.*

Fig. 6 shows side rows of luminaires mounted 3 feet on centers from side walls and 2 feet from end walls.

Step 2. *Deduct both side wall rows of luminaires from total number of luminaires.*

18 luminaires (total)
−14 luminaires (2 side rows)

4 luminaires (balance)

Step 3. *Divide number of luminaires per row into balance remaining to determine number of rows.*

$$\frac{\text{4 luminaires balance}}{\text{7 luminaires per row}} = .6 \text{ row}$$

Since all rows must be full, three luminaires should be added to complete the third row.

$$3 + 4 = \frac{\text{7 luminaires (balance)}}{\text{7 luminaires per row}} = 1 \text{ row}$$

Step 4. *Divide number of spaces between rows (number of remaining rows plus one integral) into the remaining width of the room after deducting total distance between outer rows and side walls. The result will be the width of luminaire spacing on centers between rows.*

20 feet (total width)
−6 feet (side wall spacing)

14 feet (remaining width)

$$\frac{\text{14 feet (remaining width)}}{\text{2 (number of rows plus one)}} = \text{7-foot spacing between center line of rows (see Fig. 7)}$$

In an industrial lighting layout where it is desirable to establish side wall spacing equal to one-half the spacing between luminaires, the following procedure may be used.

Problem IV: To light an 80- by 66-foot industrial plant with a 20-foot ceiling, using 56 8-foot luminaires mounted at 18 feet. The manufacturer recommends a maximum spacing of .8 of mounting height, therefore, the luminaires should not be spaced more than 14 feet apart.

Step 1. *Divide total number of luminaires required by number of luminaires per row.*

$$\frac{\text{56 luminaires (total)}}{\text{8 luminaires per row}} = 7 \text{ rows}$$

Step 2. *Divide total width of area by number of rows for spacing between rows.*

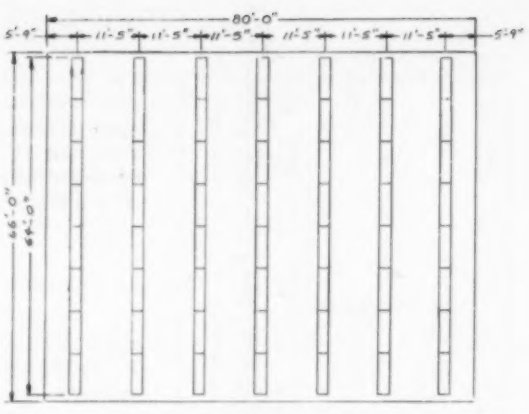


Figure 8. In this 80- x 66-foot industrial area where spacing should not exceed .8 of mounting height, luminaires are mounted at 14 feet, spaced on 11-foot 5-inch centers, with the center line of the side rows 5 feet 9 inches from side walls.

$$\frac{\text{80 feet (total width)}}{\text{7 rows}} = \text{11 feet 5 inches (spacing between rows)}$$

Step 3. *To determine spacing between outer rows of luminaires and end walls, divide spacing between rows in half.*

$$\frac{\text{11 feet 5 inches (spacing between rows)}}{2}$$

= 5 feet 9 inches (spacing between outer row of luminaires and end wall — Fig. 8).

For simplicity of demonstration of the "four-step" method, small areas have been used in the preceding examples. However, this spacing system is useful in planning engineered layouts for all sizes and types of installations, including wall-to-wall ceilings, and in addition, contributes to the advantage of using the lumen formula method in predetermining footcandle intensities.

NEW IES Recommended Levels of Illumination — what they are, how they were determined. Reprints of this important August 1958 IE feature for levels then determined* are still available (latest printing makes 25,000 copies distribution). Twenty cents each in any quantity. Order now from Publications Office, IES Headquarters, 1860 Broadway, New York 23, N. Y.

*Recommendations for Schools and Churches and Synagogues appear in February IE.

INSTALLATION AT WALSTON & CO., STOCKBROKERS, 72 WALL STREET, NEW YORK, N. Y.

Lighting a Stock Board

LIGHTING OBJECTIVE: To provide uniform illumination on Teleregister Stock Quotation Board so that the quotations and Trans-Lux screens can be read with ease.

GENERAL INFORMATION: The Teleregister Board automatically records changes in prices of the stocks listed on the stock exchange. The Board consists of eight panels each five feet six inches in width, for a total width of forty-four feet. The board is six feet eight inches in height and is mounted four feet from the floor. Three panels have back-lighted Trans-Lux Screens that transmit additional pertinent information.

INSTALLATION: Board illumination is provided by eight Miller Company catalog No. K-1090D two-lamp louvered units, with a tilted parabolic Alzak aluminum reflector behind each 40-watt T-12 cool white rapid start fluorescent lamp. The louver blades have a matte black finish, and the longitudinal blades are individually adjustable to permit control of vertical illumination.

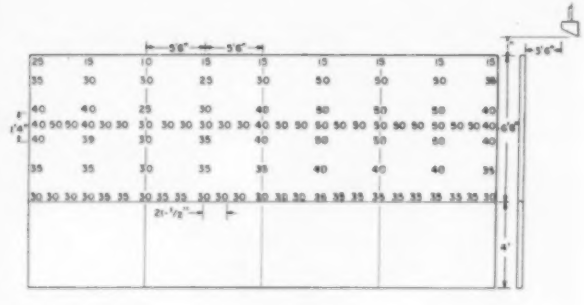
The luminaires are installed one foot above the top of the board and three feet six inches from the face of the board as shown in Fig. 2. Each four-foot unit is parallel to the board face it illu-

(over)

A.I.A. File No. 31

Figure 2. (left). Close-up showing illumination on stock board from two-lamp louvered units.

Figure 3. (below). Maintained vertical illumination distribution on face of board.



minates, and blank filler sections are installed between units to obtain the more pleasing appearance of a continuous row.

The louvers are adjusted to obtain the uniform, maintained vertical illumination distribution shown in Fig. 3. The louvers are adjusted differently for the right- and left-hand halves of the board so that the illumination on the Trans-Lux screen portions will be minimized.

Lighting designed by Daniel P. Broaders and Albert K. Otto, Engineers, DeCoppet and Doremus, 72 Wall Street, New York, N. Y., and installed by Consolidated Electrical Construction, 205 E. 42nd Street, New York, N. Y. Custom lighting equipment designed by T. Lepak, The Miller Co., Meriden, Conn.

Lighting data submitted by S. J. Pritchard, The Miller Co., New York, as an example of good lighting practice and to aid in the design of similar installations.

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Economics of Fluorescent Reflector Lamps

By C. N. CLARK
N. F. MEYER

In recent years there has been a trend toward the use of lamps with built-in reflectors, especially filament and mercury vapor types. Some of the advantages of such reflectorized lamps are: increased utilization of light, improved maintenance of light output when dirt collects on lamps and luminaires, greater convenience in relamping and maintenance, and in some cases, simpler, more economical luminaire construction. A few years ago, a fluorescent lamp with a built-in reflector was developed and marketed by a European lamp manufacturer.[1] Further research on and development of lamps of this type in the United States has led to the commercial availability of fluorescent reflector (FR) lamps in several sizes, including 40-watt rapid start, 48-inch and 96-inch T12 slimline, 90-watt, etc. It has been suggested that the use of FR lamps instead of regular F lamps may result in increased illumination, more favorable light distribution, or reduced cleaning costs in a variety of specialized and general lighting applications. This paper presents, for several types of *general* lighting equipment, an evaluation of the extent of these possible advantages, and provides data from which the user of lighting can estimate comparative illumination levels and lighting costs for his particular general lighting system.

Lamp Characteristics

The structure of FR lamps is suggested by the cross-section diagram of Fig. 1. They are electrically and mechanically similar to regular fluorescent (F) lamps, and the two types may be installed interchangeably. The difference between them is that the FR lamps have a reflective coating, consisting of a layer of inert white powder between the phosphor layer and the glass bulb, extending the full length of the bulb and covering about two-thirds of its circumference. This reflective coating redirects a high percentage of the total light generated by the phosphor out through the non-reflectorized strip, or opening. A small portion of the light is emitted *through* the reflector.

The crosswise candlepower distribution of an FR lamp is shown in Fig. 2, compared to that of a regular F lamp. While the light distribution of the FR lamp is noticeably asymmetric, both logic and experience indicate that the degree of directional control of light possible in such a lamp is not nearly as great as can be obtained from reflectorized filament or mercury lamps. This is because mercury and filament reflector lamps generally utilize a reflecting surface which is relatively large in comparison to the size of the actual light source — the arc or the filament, whereas in the FR lamp, the reflector is, in effect, no larger than the light source — the diffusely-emitting phosphor layer.

The lumen output of the FR lamp represented in Fig. 2 is 87 per cent of that of the F lamp. This is representative of the reduction in output to be expected of commercially-available FR lamps *vs.* F lamps made with comparable phosphors and processing techniques. The light output and degree of asymmetry of light distribution of FR lamps depend mainly on the reflectance/transmittance characteristics of the reflective coating and the angular extent of the reflector around the lamp circumference. An opaque reflector of high reflectance would give significantly greater directional control of light, but this would be at the expense of decreased total light output and decreased indirect component when the lamp is mounted with the opening downward. The opening size (angle

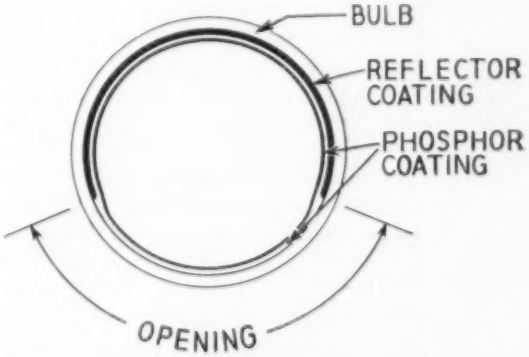

Figure 1. Schematic cross-section diagram of FR lamp.

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Authors: General Electric Co., Cleveland, Ohio.

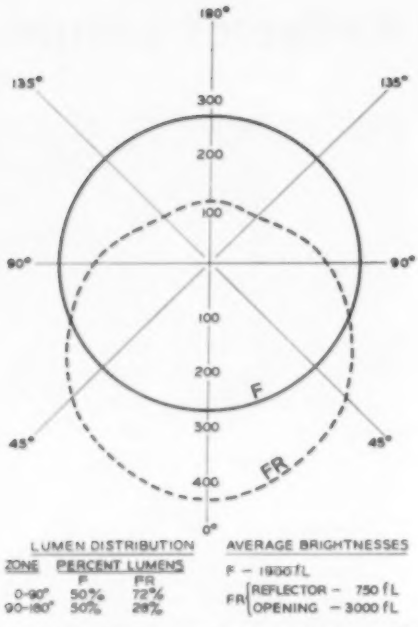


Figure 2. Approximate crosswise candlepower distributions of comparable 40-watt T-12, F and FR lamps. Lengthwise candlepower distributions of both lamps are similar to each other in shape. Lumen distribution data are based on measurements of total flux rather than on these curves. Brightness data are for viewing perpendicular to the lamp and, for the FR lamp, in the 180- and 0-degree directions.

around the lamp circumference) and reflectance/transmittance characteristics of the reflective coating have been selected to give the optimum compromise between increasing light control and decreasing light output, so as to obtain the most utilized light under a variety of lighting application conditions.

Effects on Light Utilization

The directional light control properties of FR lamps operate in several ways to increase the utilized light from direct and direct-indirect luminaires for general lighting service. Some of these ways are depicted schematically in Fig. 3, in which it is assumed that a regular F lamp and an FR lamp are mounted horizontally beneath an infinitely broad reflector (or ceiling). With clean lamps and reflector, the theoretical distribution of 100 lumens from the F lamp and 87 lumens from the FR lamp would be as shown in the diagram. F lamps deliver more total lumens downward toward the work plane. The efficiency of the lamp-reflector system is 90 per cent for the F lamp, 94 per cent for the FR lamp. In real reflectors that fit closer to the lamps, thus tending to trap a greater fraction of the light, the efficiency advantage of the FR lamps would tend to be somewhat greater than shown. With dirty lamps and reflectors, FR lamps deliver more total lumens downward. Efficiency is decreased more with the F lamp than with the FR lamp, because the FR lamp directs a smaller proportion of its light upward to be absorbed by dirt on the lamp or the reflector, or by trapping between the lamps and the reflector. The difference in the extent to which dirt affects system efficiency is indicated by the maintenance factor data given in Fig. 3.

Not illustrated in Fig. 3 is the fact that in practical luminaires with a direct component of light, FR lamps tend to slightly increase the flux ratio (downward concentration of light). This increase results in slightly higher utilization factors. Furthermore, in direct-indirect luminaires with an upward component of light, FR lamps tend to direct a higher percentage of luminaire output downward, in addition to increasing the flux ratio of the downward component. Both these effects lead to higher utilization factors. Of course, changing the proportion of upward *vs.* downward light in this manner is not always desirable, because the upward light is often required for such reasons as visual comfort in the installation.

To summarize: Fluorescent reflector lamps in general lighting luminaires of the direct or direct-indirect type tend to deliver a higher percentage of their light output to the work plane than regular fluorescent lamps because:

(1) Their smaller upward component results in less light loss by trapping and reflector absorption, so that the luminaire efficiency is higher.

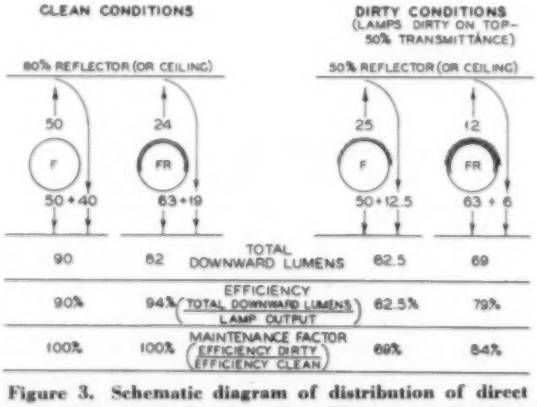


Figure 3. Schematic diagram of distribution of direct and reflected light flux from F *vs.* FR lamps under clean and dirty conditions. Figures are based on 100 lumens from F lamps and 87 lumens from FR lamps, which are representative of the relative outputs of the two types. Upward and downward flux are divided as tabulated in Fig. 2.

(2) Their directional characteristics tend to give most luminaires a slightly higher flux ratio.

(3) Their directional characteristics modify the normal light distribution of direct-indirect luminaires, increasing the proportion of downward light.

(4) Their output is less influenced by normal accumulation of dirt on the reflector side of the lamp.

(5) Their smaller upward component results in luminaire output being less influenced by accumulation of dirt on reflecting surfaces designed to redirect light downward.

On the other hand, these lighting advantages of FR lamps as compared to regular F lamps may be partly or entirely offset by one or more of the following factors:

(1) Light output of FR lamps is 12 to 15 per cent lower than that of comparable F lamps of the same size and wattage, due to absorption by the built-in reflector.

(2) FR lamps are inherently more expensive.

(3) The opening of the FR lamp is considerably higher in brightness than the brightness of comparable F lamps, which may lead to greater direct or reflected glare.

(4) When FR lamps are mounted behind and "aimed" at louvers or diffusers, their directional nature tends to give somewhat less uniformity of brightness between rows of lamps than would be obtained with regular F lamps.

The reduction in light output of FR lamps compared to regular F lamps is especially significant. It means that the total of the increases in luminaire efficiency, utilization factor and maintenance factor obtainable in an installation by using FR lamps in place of regular F lamps must be about 15 per cent before the illumination results with FR lamps will equal those with F lamps. Beyond 15 per cent, FR lamps will begin to show advantages.

Actual installation conditions differ, in several important respects, from the idealized theoretical situation illustrated in Fig. 3. Reflectors generally intercept more than just the upper-hemisphere flux from the lamps. Different degrees of light trapping take place in various luminaires. Upward and downward light distribution is influenced to varying degrees by luminaire design. Dirt collects on the bottoms of lamps as well as the tops, although generally not as much. Because of these practical variables, light distribution, luminaire efficiency and maintenance factor cannot be determined by such analyses as in Fig. 3 with sufficient accuracy to permit useful predictions of lighting results or estimates of relative economic value between FR and F lamps. Therefore, a series of tests was devised to provide data which would allow reasonably accurate lighting and cost comparisons.

Photometric Tests

Several representative commercial and industrial luminaire-types were tested, using 40-watt rapid start FR and F lamps. Photometric measurements were made under clean conditions and under one or more simulated conditions of dirt accumulation on lamps and luminaire. From these tests and certain assumptions to be explained later, coefficients of utilization and maintenance factors for both lamp types are derived.

It seems reasonable to assume that in a given installation dirt would accumulate in the same way and at an equal rate on both FR and F lamps. In the tests, this condition was obtained by using glass sleeves with different amounts of dirt on them (in the form of distributed particles of medium-gray paint). In any given test, the same matched pair of sleeves was used over clean lamps of both types, to simulate actual direct accumulation on the lamps.

A study of existing data[2,3] and observation of dirt collection on lamps, indicated that:

(1) Under representative conditions, about three to five times as much dirt collects on the top of lamps as on the bottom.

(2) Under extremely dirty conditions *(e.g.,* a welding shop or foundry), light transmission on the top of the lamp may be reduced by about 30 per cent.

Therefore, pairs of 2⅛-inch diameter (2-inch I.D.) glass sleeves were prepared, ranging from clean to maximum-dirt condition of 30 per cent reduction in transmission on one side of the sleeve, graded to 10 per cent reduction on the other. A dirty-sleeve absorption of this sort is designated hereafter as "30-10;" and a clean sleeve as "0-0." Absorption was determined by measuring the difference in light transmission of the tube before and after painting. A small rubber spacing pad one-quarter-inch thick was affixed just inside the end of each sleeve along the axis of maximum dirt accumulation. In the tests, these pads rested upon the lamp bases, thereby insuring that the sleeve area of maximum absorption was always in the same position at the top of the lamp and the lamp was centered in the sleeve.

Dirt accumulation on the luminaires was simulated by spraying all reflecting surfaces with grey lacquer of the desired reflectance. Admittedly, dirt does not accumulate this uniformly in practice, but it does not seem likely that the *comparative* results between FR and F lamps would be seriously im-

paired by this uniform simulated dirt. Reflectances representing dirt on luminaires were selected after consideration of available data.[2,3,4] From the test results, they appear to have been appropriate choices.

Table I shows the luminaire types tested under clean conditions and under various conditions of simulated dirt on luminaires and lamps. Standard photometric procedures[5] were followed to obtain luminaire efficiency, flux ratio and light distribution. In all cases, the FR lamps were mounted with their maximum candlepower downward. Typical candlepower distributions obtained are shown in Figs. 4 and 5. For clean conditions, lamps and luminaires were photometered both with and without clean sleeves. For dirty conditions, lamps and luminaires were photometered with the appropriate dirty sleeves in place. Luminaire efficiencies under *clean* conditions were calculated in each case by taking the usual ratio of luminaire output to bare lamp output, without any sleeves. Luminaire efficiencies under the various *dirty* conditions shown were calculated from this expression:

$$\frac{\text{dirty luminaire efficiency with dirty sleeves}}{\text{clean luminaire efficiency with clean sleeves}} \times \text{luminaire efficiency under clean conditions (no sleeves).}$$

This procedure serves to cancel out the effect of the sleeves themselves, leaving only the effect of the dirt, as if it were on the lamps rather than on the sleeves. It was assumed that flux ratio and light distribution from the luminaires, although in all cases measured with sleeves on the lamps, are the same as would be found if the same dirt were on the lamps rather than on the sleeves.

The luminaire efficiencies in Table I are in substantial agreement with the trends suggested by the analysis in Fig. 3, although those for the louvered direct-indirect luminaire may at first appear anomalous. In this case, luminaire efficiency is about the same for both F and FR lamps under clean conditions, and also under dirty conditions. The reason for this is undoubtedly that, since the luminaire has an open top and louvered bottom, upward light from the lamps is emitted from the luminaire with about the same losses as downward light, rather than with greater lossse due to reflector absorption, as in the case of open direct luminaires. When lamps and luminaire have dirt applied, loss of downward light from the lamps due to increased absorption by the louvers approximates the loss of upward light due to dirt on the top of the lamps. This can be deduced from the fact that the ratio of upward to downward light does not change appreciably in going from clean to dirty conditions. Thus the directional effect of the FR lamps has no advantage as far as luminaire efficiency is concerned, although it does improve utilization by shifting more of the luminaire output downward.

Table II presents coefficients of utilization (CU's) calculated[6] from the data in Table I.

Maintenance Factors

From the test data in Table I, it is obvious that as dirt accumulates on lamps and luminaire surfaces, the efficiency of the luminaire decreases and flux ratio changes slightly for both F and FR lamps. For a given room with specific ceiling, wall, and floor reflectances, flux ratio determines the utilization factor of luminaires with no upward light, and influences the overall utilization factor of luminaires with direct and indirect components. Therefore, both luminaire efficiency and utilization factor are influenced by dirt collection.

TABLE I — Summary of Photometric Test Results for Four Luminaire-Types under Clean Conditions and Simulated Dirty Conditions, Using 40-watt Rapid Start F and FR Lamps.

Luminaire Type		Industrial Closed-Top			Two-Lamp Bare Channel*			Louvered Direct-Indirect		Industrial Open-Top
Reflectance of Reflector		82% (clean)	60%	40%	86% Channel 84% Ceiling (clean)	86% Channel 65% Ceiling	60% 50%	82% (clean)	65%	80% (clean)
Approximate Per Cent of Lamp Output Absorbed by Dirt on Sleeves (up-down)		0-0	20-5	30-10	0-0	0-0	20-5	0-0	15-3	0-0
Luminaire Efficiency										
luminaire output / clean lamp output	F	80.8%	57.6	46.3	87.0	84.1	64.2	83.0	65.0	89.6
	FR	90.1%	72.6	63.2	96.2	95.6	79.2	83.8	64.7	92.7
Flux Ratio	F	.364	.361	.359	.297	.294	.292	.445	.481	.390
	FR	.368	.370	.372	.320	.320	.320	.459	.488	.403
Light Distribution										
per cent lamp output up	F	0	0	0	0	0	0	46	36	24
per cent lamp output down		81	58	46	87	84	64	37	29	66
	FR	0	0	0	0	0	0	25	20	11
		90	73	63	96	96	79	59	45	82

*Channel mounted on center of 4' x 8' panel simulating ceiling of indicated reflectance. Panel and channel together form the "luminaire" tested.

Figure 4. Mean candlepower distributions of a 2-lamp, 40-watt, closed-top industrial luminaire tested with F and FR lamps. "Clean" data are for clean lamps and luminaire. "Dirty" data are for reflector of 40 per cent reflectance, with dirt on lamps absorbing 30 per cent of upward light from lamps and 10 per cent of downward light. Numbers in parentheses are approximate lumen outputs of the luminaire under the conditions indicated, based on 2500-lumen F lamps and 2180-lumen FR lamps.

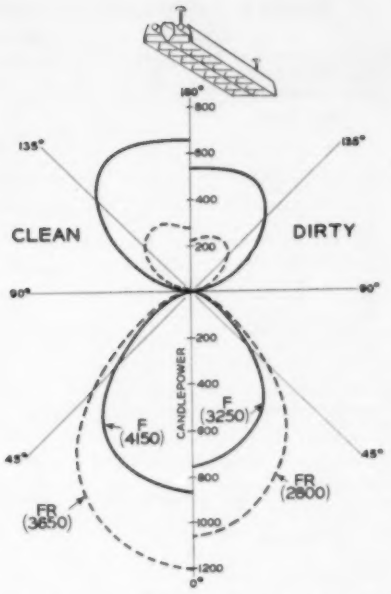


Figure 5. Mean candlepower distributions of 2-lamp, 40-watt, direct-indirect louvered luminaire tested with F and FR lamps. "Clean" data are for clean lamps and luminaires; "dirty" data for luminaires and louvers of 65 per cent reflectance with dirt on lamps absorbing 15 per cent of upward light and 3 per cent of downward light. Numbers in parentheses are approximate total (upward plus downward) lumen outputs of the luminaire under conditions indicated, based on 2500-lumen F lamps and 2180-lumen FR lamps.

In this discussion, maintenance factor for a particular degree of dirt accumulation on luminaire and lamps is given by:

$$MF_i = \frac{\text{Luminaire efficiency} \times \text{utilization factor (dirty conditions)}}{\text{Luminaire efficiency} \times \text{utilization factor (clean conditions)}}.$$

The term MF_i is used to denote instantaneous maintenance factor as opposed to mean maintenance factor (averaged over a period of time), for which the term MF is used. Luminaire efficiency in the above expression is defined, under each condition, by $\frac{\text{luminaire output}}{\text{clean lamp output}}$, as in Table I.

Defining MF_i in this way excludes the effect of lamp-lumen depreciation throughout life, and also the effect of dirt accumulation on room surfaces. It accounts only for dirt accumulation on lamps and luminaires, and applies to a room of specific room ratio and reflectances. In the following discussions we have assumed a C-room with constant reflectances. Lamp-lumen maintenance can be considered separately, and is used as a separate factor in the calculation of average maintained lumens per luminaire in Tables V and VI.

It is quite evident from the test data that FR lamps, despite their lower light output, may provide significantly higher illumination than F lamps in some installations after appreciable dirt has accumulated, but will have less advantage, or in many cases a disadvantage, when luminaires and lamps are kept relatively clean. The question then arises: Is it more advantageous from the standpoint of average maintained illumination and cost of light to use FR lamps in place of regular F lamps, cleaning lamps and luminaires relatively seldom; to use regular F lamps, cleaning lamps and luminaires relatively often; or to use FR lamps, cleaning lamps and luminaires relatively often?

The answer is not a simple one, since maintained illumination will depend upon which lamp type is used, as well as the type of luminaire, the room ratio and reflectances, the type and rate of accumulation of dirt and the frequency of cleaning. The comparative cost of light will depend upon these things plus the usual cost factors, especially the expense of cleaning lamps and luminaires.

TABLE II — Coefficients of Utilization[1] for Four Luminaire-Types Using F or FR Lamps. (Based on Data in Table I.)

Room Reflectances (Ceiling-walls-floor)		80-50-10		50-30-10		30-10-10		Luminaire Type
Lamp Type		F	FR	F	FR	F	FR	
Room Index (Room Ratio)	J (.6)	.34	.38	.27	.31	.23	.26	Industrial closed-top
	F (1.5)	.60	.67	.52	.59	.48	.54	
	C (3.0)	.73	.81	.66	.74	.62	.70	
	A (5.0)	.79	.88	.73	.82	.70	.79	
	J (.6)	.34	.39	.26	.31			Industrial open-top
	F (1.5)	.61	.67	.50	.58			
	C (3.0)	.73	.81	.63	.72			
	A (5.0)	.80	.87	.70	.80			
	J (.6)	.33	.38	.25	.30			Two-lamp bare channel
	F (1.5)	.60	.68	.51	.59			
	C (3.0)	.74	.84	.66	.76			
	A (5.0)	.82	.92	.75	.85			
	J (.6)	.27	.33	.20	.27			Louvered direct-indirect
	F (1.5)	.49	.57	.37	.48			
	C (3.0)	.60	.69	.48	.59			
	A (5.0)	.66	.74	.52	.64			

[1]To be used with the rated lumen output of the lamp type indicated.

TABLE III — Coefficients of Utilization[1] for Luminous Ceilings Using F or FR[2] Lamps.

Reflectances (cavity—walls—floor)		85-50-10		75-50-10		75-30-10		Type of Louver or Panel
Lamp Type		F	FR	F	FR	F	FR	
Room Index (Room Ratio)	J (.6)	.20	.21	.17	.19	.15	.17	2" x 2" x 2" white metal louvers
	F (1.5)	.30	.32	.27	.30	.24	.27	
	C (3.0)	.35	.37	.31	.35	.29	.33	
	A (5.0)	.37	.39	.33	.37	.32	.36	
	J (.6)	.21	.22	.17	.18	.14	.15	Corrugated vinyl plastic sheet
	F (1.5)	.42	.44	.36	.38	.32	.34	
	C (3.0)	.55	.58	.47	.50	.45	.48	
	A (5.0)	.61	.64	.53	.56	.52	.55	

[1]To be used with the rated lumen output of the lamp type indicated.
[2]CU's for F lamps are taken directly from General Electric Co. Large Lamp Department publication LS-173, *Essential Data for Lighting Design*. CU's for FR lamps are based on those for F lamps and tests comparing the luminaire efficiency for a single FR lamp *vs.* a single F lamp in a cavity 2 feet by 4 feet by 6 inches, of variable reflectance covered with either metal louvers or vinyl plastic. Efficiency was somewhat higher for the FR lamps, but flux ratio did not vary between FR and F lamps. Thus, CU's for FR lamps are higher, and are in proportion to the luminaire efficiency the lamps provide.

TABLE IV — Mean Maintenance Factors to Account for Dirt on Lamps and Luminaires in a C-Room with Indicated Reflectances[1] (Mean Lumen Maintenance Factor for Lamps NOT Included).

Luminaire Type	Reflectance of Reflector at Maximum Depreciation	Dirt Conditions	Room Reflectances (Ceiling, Walls, Floor)	Lamp Type	Number of Cleanings per Year[2] 0	½	1	2
1. Industrial Closed-top	60%	Average	80 50 10	F	.72	.76	.82	.89
				FR	.81	.84	.88	.93
	40%	Heavy	50 30 10	F	.59	.65	.71	.78
				FR	.72	.76	.80	.85
	20%	Extra heavy	30 10 10	F	*.46*	*.51*	*.56*	*.61*
				FR	*.62*	*.65*	*.69*	*.72*
2. Industrial Open-top	60%	Heavy	50 30 10	F	*.73*	*.79*	*.84*	*.90*
				FR	*.83*	*.85*	*.89*	*.93*
3. Two-lamp Bare Channel	60%	Slightly worse than average	65 40 10	F	.79	.81	.86	.91
				FR	.85	.87	.90	.93
4. Louvered Direct-Indirect	65%	Average	65 40 10	F	.79	.82	.86	.91
				FR	.79	.82	.86	.91
5. Luminous Ceiling White Metal Louvers 2" x 2" x 2"	50% cavity	Slightly worse than average	75 cavity 50 10	F	*.66*	*.71*	*.76*	*.82*
				FR	*.72*	*.76*	*.80*	*.85*
6. Luminous Ceiling Corrugated Vinyl Plastic Sheet	50% cavity	Slightly worse than average	75 cavity 50 10	F	*.54*	*.61*	*.68*	*.76*
				FR	*.59*	*.65*	*.71*	*.78*

[1]Figures for luminaire-types 1, 5 and 6 can be applied without significant error to rooms of other room index and reflectances.
[2]Zero cleanings per year implies luminaires with several-years' dirt accumulation and no cleaning of luminaires when they are relamped.
NOTE: MF's for no cleanings per year are in each case used as the base from which the MF's for ½, 1, and 2 cleanings per year are determined as described in Fig. 6 and the text. The italicized data are based on estimated, rather than measured, no-cleaning MF's.

The relative maintained illumination for F *vs.* FR lamps in the various luminaire types, for various dirt conditions and cleaning schedules, can be found by standard lighting design calculation methods using the coefficient of utilization data in Tables II and III, and the mean maintenance factors (MF's) from Table IV for corresponding conditions. Here is how these MF's were calculated: The tests provide luminaire efficiency and utilization factor data for clean conditions and for one or two dirty conditions for each luminaire type. These data enable calculation of instantaneous maintenance factor (MF_1) for each luminaire and lamp type. For example, from the data in Table I, the MF_1 for F lamps in the industrial closed-top luminaire with 40 per cent reflectance is:

$$MF_1 = \frac{46.3 \times .817}{80.8 \times .820} = 0.57.$$

Similarly, that for the FR lamps is 0.70. In an installation where dirt conditions result in an amount and distribution of dirt similar to that which we applied to the luminaire and lamp in this case, these would be the instantaneous maintenance factors at some point in time. Reference to Fig. 2 of the VandenBoom-Egeler (V-E) paper[2] shows that the value of 0.57 for F lamps is very close to the instantaneous maintenance factor corresponding to 25 months in service on the depreciation curve they label "welding shop." It is assumed that: (1) this degree of dirt collection in our test of F lamps corresponds to 25 months service in such a location, and (2) the shape of the V-E depreciation curve represents that which would be followed in arriving at this MF_1. This V-E depreciation curve is shown in Fig. 6, together with the above MF_1's based on our tests of both F and FR lamps in the 40 per cent reflector, and the comparable depreciation curves derived to correspond to our test conditions. The test value of MF_1 for the FR lamps must also correspond to a 25-month accumulation of dirt, since the dirt conditions in the test were identical, and dirt can be expected to build up on FR lamps at the same rate as on F lamps.

It is now possible to find mean maintenance factors by averaging a curve of MF_1 over periods of time corresponding to various intervals between cleanings of lamps and luminaires. The results of such calculations of MF are also indicated in Fig. 6, for three different cleaning intervals.

It is also assumed that since the V-E depreciation curve appears to be relatively flat beyond 25 months, the MF_1 at 25 months is approximately equal to the MF for a period of four or five years between cleanings, in effect, no cleaning, as described in the tables. But even if lamps and luminaires are not cleaned for very long periods, dirty lamps will be replaced with clean ones, usually about every two years. Table I of the V-E paper and other maintenance data[3] suggest that from $^1/_5$ to $\frac{1}{2}$ (perhaps $\frac{1}{4}$ on the average) of the total depreciation in illumination is generally due to dirt on lamps only. Thus, the no-cleaning MF can be corrected for the fact that lamps are, in effect, cleaned about every two years, by adding $\frac{1}{4}$ the difference between the no-cleaning MF and the MF for $\frac{1}{2}$ cleaning per year. In the example, this is about two percentage points.

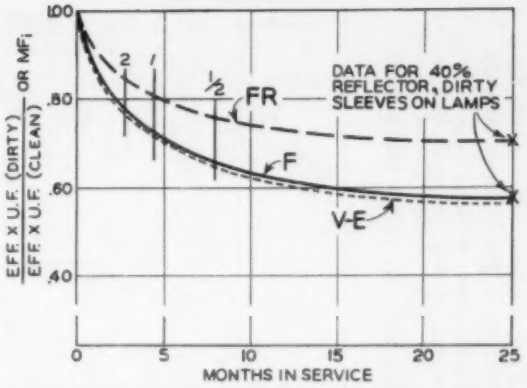


Figure 6. Curves of depreciation in illumination due to dirt on lamps and luminaires, derived for F and FR lamps in a location with severe dirt conditions. Curve V-E is the "welding shop" curve from Fig. 2 of the VandenBoom-Egeler paper.[2] As discussed in the text, the curves for F and FR lamps are derived from the V-E curve by assuming that the MF_1 values found from the test data in Table I, for a closed-top industrial fixture with 40 per cent reflectance, correspond to 25 months in service; then finding curves that pass through these MF_1's such that the depreciation from unity at any point in time on each curve is a constant fraction of that at the corresponding point on the V-E curve. In this way, the "shape" of the V-E curve is retained and its height adjusted to fit the MF_1's found from the test data.

MF_1's at the intersections of the curves with the vertical lines numbered 2, 1 and ½ are the mean maintenance factors for 2, 1 and ½ cleanings per year, as found by averaging the respective curves over corresponding periods of time.

The foregoing procedure was followed for the three luminaires tested under dirty conditions and also for three other luminaire-types shown in Table IV, for which photometric tests were made under clean conditions only. For the latter luminaires, no-cleaning MF's were derived by calculations that took into consideration the light distribution, reflector reflectance and room reflectances, under clean and assumed dirty conditions. In all cases, it was assumed that the MF_1 found by tests or calculation corresponded to 25 months in service. Then,

TABLES V and VI — Comparisons of Light Output and Lighting Costs for Several Typical Fixtures and Dirt Conditions, Showing the Effect of Using Fluorescent Reflector Lamps and Regular Fluorescent Lamps and of Cleaning Lamps and Fixtures at Two Different Intervals.

Data for regular F lamps with no cleaning of lamps or fixtures are the 100 per cent base for each fixture-type and dirt condition. Variations of light output and associated operating and total costs for the several lamp types and cleaning schedules are, in each case, compared graphically with the base data which are given immediately below the bar graphs in each table.

All calculated values are based on estimates given at the bottom of each table and conditions given below Table VI, together with coefficients of utilization and maintenance factors from tables in text.

TABLE V

INDUSTRIAL LUMINAIRES

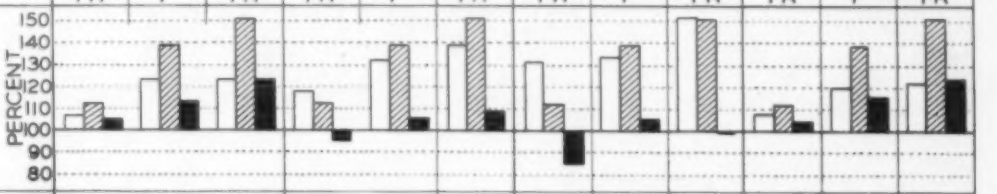
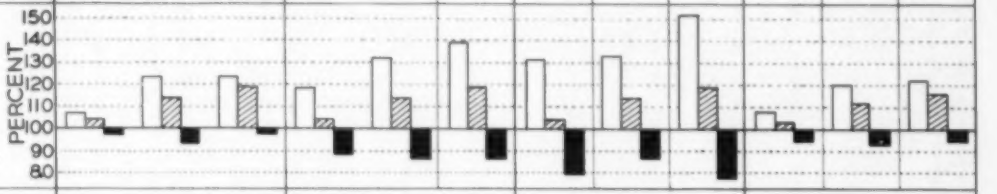
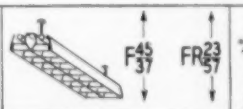
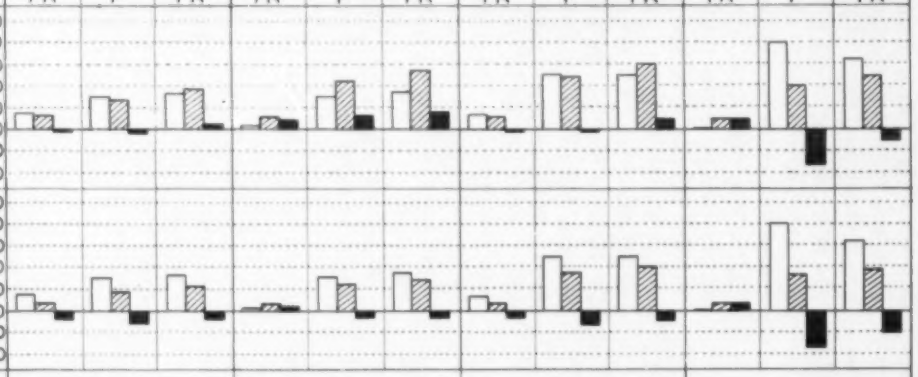
FIXTURE TYPE, AND LIGHT DISTRIBUTION									
DIRT CONDITIONS (and reflector reflectance before cleaning)	AVERAGE (60%)			HEAVY (40%)			EXTRA HEAVY (20%)			HEAVY (60%)		
ROOM REFLECTANCES (ceiling — walls — floor, %)	80 – 50 – 10			50 – 30 – 10			30 – 10 – 10			50 – 30 – 10		
CLEANING SCHEDULE	No Cleaning	2 Cleanings Per Year		No Cleaning	2 Cleanings Per Year		No Cleaning	2 Cleanings Per Year		No Cleaning	2 Cleanings Per Year	
LAMP TYPE	FR	F	FR	FR	F	FR	FR	F	FR	FR	F	FR
OPERATING COSTS and LIGHT OUTPUT Operating costs include electrical energy, cleaning lamps and fixtures, and relamping Relative lumens per fixture maintained on work plane (in % of base data below) Relative operating cost per fixture per year (in % of base data below) Relative annual operating cost for equal maintained illumination (in % of base data below)												
TOTAL COSTS and LIGHT OUTPUT Total costs include operating costs plus owning costs (given below) Relative lumens per fixture maintained on work plane (in % of base data below) Relative total cost per fixture per year (in % of base data below) Relative total annual cost for equal maintained illumination (in % of base data below)												
BASE DATA, calculated per the Ben Amick method from stated estimates and conditions together with data from tables in text, for regular F lamps with no cleaning of lamps or fixtures. Figures represent an average over several years. Lumens per fixture maintained on work plane	2320			1710			1250			2080		
Operating cost per fixture per year	$4.35			$4.35			$4.35			$4.35		
Annual operating cost for 100 fc	18.7¢/SQ.FT.			25.4¢/SQ.FT.			34.8¢/SQ.FT.			20.9¢/SQ.FT.		
Total cost per fixture per year	$11.65			$11.65			$11.65			$13.65		
Total annual cost for 100 fc	50.2¢/SQ.FT.			68.2¢/SQ.FT.			93.2¢/SQ.FT.			65.6¢/SQ.FT.		
ESTIMATED COSTS												
Estimated cost of cleaning one fixture	$0.85			$0.85			$0.85			$0.85		
Estimated labor cost of replacing one lamp	$1.00			$1.00			$1.00			$1.00		
Estimated annual owning cost per fixture (15% of fixture, wiring, and installation cost)	$7.30			$7.30			$7.30			$9.30		

TABLE VI

COMMERCIAL LUMINAIRES

FIXTURE TYPE, AND LIGHT DISTRIBUTION	F 0/84 FR 0/96	 F 45/37 FR 23/57	F 0/44 FR 0/49 WHITE METAL LOUVER 2 LAMPS 3'X4' SECTION	F 0/54 FR 0/57 VINYL PLASTIC 2 LAMPS 4'X4' SECTION
DIRT CONDITIONS (and reflector reflectance before cleaning)	CHANNEL-65%, CEILING-50%	AVERAGE 65%	SLIGHTLY WORSE THAN AVERAGE CAVITY-50%	SLIGHTLY WORSE THAN AVERAGE CAVITY-50%
ROOM REFLECTANCES (ceiling — walls — floor, %)	65 - 40 - 10	65 - 40 - 10	75(CAVITY) - 50 - 10	75(CAVITY) - 50 - 10
CLEANING SCHEDULE	No Cleaning / 2 Cleanings Per Year	No Cleaning / 2 Cleanings Per Year	No Cleaning / 2 Cleanings Per Year	No Cleaning / 2 Cleanings Per Year
LAMP TYPE	FR F FR	FR F FR	FR F FR	FR F FR
OPERATING COSTS and LIGHT OUTPUT Operating costs include electrical energy, cleaning lamps and fixtures, and relamping □ Relative lumens per fixture maintained on work plane (in % of base data below) ▨ Relative operating cost per fixture per year (in % of base data below) ■ Relative annual operating cost for equal maintained illumination (in % of base data below)	 PERCENT 150 140 130 120 110 100 90 80			
TOTAL COSTS and LIGHT OUTPUT Total costs include operating costs plus owning costs (given below) □ Relative lumens per fixture maintained on work plane (in % of base data below) ▨ Relative total cost per fixture per year (in % of base data below) ■ Relative total annual cost for equal maintained illumination (in % of base data below)	PERCENT 150 140 130 120 110 100 90 80			
BASE DATA, calculated per the Barr-Anick method from stated estimates and conditions together with data from tables in text, for regular F lamps with no cleaning of lamps or fixtures. Figures represent an average over several years.				
Lumens per fixture maintained on work plane	2430	1880	900	1120
Operating cost per fixture per year	$9.60	$10.10	$10.20	$10.20
Annual operating cost for 100 fc	39.5¢/SQ.FT.	57.3¢/SQ.FT.	$1.13/SQ.FT.	$0.91/SQ.FT.
Total cost per fixture per year	$15.60	$19.05	$17.80	$18.20
Total annual cost for 100 fc	64.0¢/SQ.FT.	$1.01/SQ FT	$1.98/SQ FT	$1.63/SQ.FT.
ESTIMATED COSTS				
Estimated cost of cleaning one fixture	$0.60	$1.10	$1.50	$1.50
Estimated labor cost of replacing one lamp	$0.50	$1.10	$1.25	$1.25
Estimated annual owning cost per fixture (15% of fixture, wiring, and installation cost)	$6.00	$8.95	$7.60	$8.00

Conditions

- Room Index — C (3.0 room ratio)
- Burning Hours per Year — 3000
- Energy Rate — Table V: 1¢/kwh; Table VI: 3¢/kwh
- Ballasts — Two 40-watt preheat, 16 watts loss

Lamp Data

	Price (70% of list)	Life (hours)	Initial Lumens	Mean Lumens
F40T12/RS	$0.91	7500	2500	2200
FR40T12/RS	1.57	7500	2200	1890

from Fig. 2 of the V-E paper, the depreciation curve whose 25-month point most closely corresponded to the experimental MF_1 for F lamps, was used as described above for calculating mean MF's for the three cleaning schedules shown in Table IV.

Economic Comparisons

In order to provide a comprehensive comparison of FR *vs.* F lamps, from the standpoint of illumination results and lighting costs, Tables V and VI were prepared. These tables should also be helpful to the user of lighting in deciding between FR and F lamps, and in evaluating the importance of cleaning, in order that he may attain his objective of getting the most favorable lighting results and lowest cost of light for any specific installation that corresponds to one of those summarized in the tables.

In Tables V and VI, comparative lighting results and costs are shown by bar graphs for each of the luminaire-types and dirt conditions on which CU and MF data were obtained by the tests. These bar graphs are based on conditions of installation and operation, and expense factors, that appear to be typical of actual installations of each type of luminaire. For each luminaire-type or dirt condition, all the values shown by the bar graphs are relative to those for regular F lamps with no cleaning of lamps or luminaires. Therefore, the bar graphs can be compared with each other only within each column headed by a particular luminaire-type and dirt condition.

All lumen-per-fixture and cost data were calculated in accordance with the methods proposed by Barr and Amick,[7] and are based on the conditions and estimated costs shown at the bottom of the tables, plus CU's from Tables II and III, and MF's from Table IV.

In all cases, there is a comparison between no-cleaning and two-cleanings-per-year. No cleaning implies several-years' accumulation of dirt and no cleaning of luminaire surfaces even during relamping. FR lamps generally have their greatest advantage under no-cleaning conditions. However, a new installation would take several years to reach this state. Until then, MF's for shorter cleaning intervals would apply, and the advantage of FR lamps might be considerably less. Two-cleanings-per-year is used for comparison because it has been found[2] that such a cleaning schedule results in cost-of-light being at or near a minimum for a range of conditions similar to those assumed for Tables V and VI.

One line of bar graphs in each table compares relative *operating* costs and light output for the various luminaires and dirt conditions. These comparisons will undoubtedly be of greatest interest in cases where lighting equipment is old enough to have been written off the books, so that no owning cost is involved. The set of graphs comparing relative *total (i.e.,* operating plus owning) costs and light output will apply in cases where the cost of owning luminaires is included in the lighting costs. To facilitate comparisons, the same white bar representing relative lumens-per-unit appears with the bars for both operating cost and total cost data in each individual column.

In interpreting the graphs, note that increases in the height of the white bars above the 100 per cent axis are in the favorable direction, while decreases in the height of the shaded and black bars (or longer bars below the 100 per cent axis) are in the favorable direction. The per cent value of the black bar in each group of three is equivalent to the ratio of the value of the shaded bar to the value of the white bar.

As an example of how the tables can be interpreted, consider the closed-top industrial luminaire under average dirt conditions in Table V. The bar graphs show that with no cleaning of lamps and luminaires, *operating* cost-per-luminaire with FR lamps is about 12 per cent higher (because of the increased lamp cost). Maintained illumination is 7 per cent higher. The net result is an increase of about 5 per cent in operating costs for the same illumination. *Total* cost-per-luminaire is only about 4 per cent higher with FR lamps, so that with 7 per cent higher maintained illumination, the net result is a decrease of 3 per cent in the total cost of light when FR lamps are used instead of F lamps, and luminaires are not cleaned.

On the other hand, if luminaires are cleaned twice a year, it happens that both F and FR lamps will give about 23 per cent more maintained illumination. It is obvious that operating and total costs per luminaire must be considerably higher because of the cost of cleaning. The costs per luminaire (including cleaning) would still be higher with FR lamps than with F lamps, because of lamp cost. Despite considerably increased operating costs, the total cost of light would be reduced with both lamp types when luminaires are cleaned twice a year, and F lamps would give the lowest cost of light, about 7 per cent lower than if no cleaning were done.

With this same luminaire-type and dirt condition, for the operating conditions and estimated costs stated, these conclusions can be drawn:

(1) ***Greatest maintained illumination*** would result from using either F or FR lamps, and cleaning about twice a year.

(2) ***Lowest operating cost per footcandle*** would result from using F lamps and not cleaning.

(3) *Lowest total cost of light* would result from using F lamps and cleaning about twice a year.

All luminaire-types and dirt conditions can be considered in a similar manner, and conclusions can be drawn to guide the user in his choice of lamp type and cleaning schedule.

Where actual conditions depart only slightly from those assumed in the tables, relative costs can often be re-calculated simply by applying suitable changes to the base data. For example, if the cost of cleaning for an actual case is different from the estimated cost in the table, the actual cleaning cost can be added to the base figures for operating and total cost, and new relative costs calculated. Where actual conditions depart greatly from those in the Tables, it is still possible, in many cases, to calculate relative illumination from the CU and MF Tables, and to find relative costs by the same means as was used in the Tables.

It is very important to note that the comparative lighting results and costs between FR and F lamps depend on the ratio of light output between the two types. Tables V and VI are based on FR lamps with 88 per cent of the output of the corresponding F lamps. For every per cent change in this ratio, there would be a corresponding change of about 1 per cent in the lumens-per-luminaire data for FR lamps, and a change of about 1 per cent in the opposite direction, in the lighting cost data for FR lamps.

Conclusions

From consideration of the data in Tables V and VI, the relative lighting and economic value of FR *vs.* regular F lamps in typical general lighting applications using direct and direct-indirect luminaires might be generalized thus:

UNDER LIGHT TO MODERATELY HEAVY DIRT CONDITIONS ("average" dirt conditions)

(1) With no cleaning of lamps or luminaires, FR lamps provide slightly higher maintained illumination at very slightly lower cost of light than F lamps.

(2) If lamps and luminaires are cleaned regularly on an appropriate schedule, both lamp types give significantly higher illumination. Regular F lamps provide about the same or slightly higher illumination than FR lamps, at slightly lower cost of light.

(3) **Regular cleaning** on an appropriate schedule and the use of **regular F lamps** will result in **highest maintained illumination** and **lowest cost of light.**

UNDER SEVERE DIRT CONDITIONS

1. With no cleaning of lamps and luminaires, FR lamps provide significantly higher maintained illumination and lower cost of light than do F lamps.

2. If lamps and luminaires are cleaned regularly on an appropriate schedule, both lamp types give significantly higher maintained illumination and lower cost of light. FR lamps provide higher illumination than F lamps, at about the same or slightly lower cost of light.

3. **Regular cleaning** on an appropriate schedule and the use of **FR lamps** will result in **highest maintained illumination** and **lowest cost of light.**

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DISCUSSION

G. W. CLARK:* The authors have made a very fine and impressively thorough study of the factors involved in the use of fluorescent reflector lamps for general lighting purposes. In our own lighting fixture activity, we have had to face the question of the use of these lamps in luminaires designed for the use of regular F lamps. Faced also with the same problem the authors pointed out regarding lumen ratings of FR lamps, we have published coefficients to be used with standard lamp lumens. This, of course, assumes parallel development of both types of lamps with respect to lumen output and, for photometric purposes, that the reflecting characteristics of the lamp are transferred to the luminaire. In general, our data verify those of the authors. One possible exception is in a direct-indirect louvered unit in which the coefficients were as follows:

Room Reflectances: 80/50/10

Lamp Type	F	FR
J-Room	.22	.27
A-Room	.66	.66

In general, it appears that there are conditions under which the use of FR lamps for general lighting is economical, but they are not as clear-cut as one might wish. It is the more specialized uses, including incidentally, the indirect positioning in a louvered luminaire or ceiling, which present a clearer case for the FR lamp.

H. A. ANDERSON:** In Table I, a 4- by 8-foot panel is used

*Sylvania Electric Products, Inc., Wheeling, W. Va.
**Duro-Test Corp., North Bergen, N. J.

to simulate a ceiling of indicated reflectance for the bare channel luminaire. We feel this should be done also for the louvered direct-indirect luminaire since many of these luminaires are surface-mounted or used with short stems. Therefore, the ceiling reflectance or maintenance would be important.

There are two important additional applications for FR lamps that were not considered by the authors. These have been recommended by the lamp manufacturers and are as follows:

(1) Cove Lighting — FR lamps are aimed at the ceiling which becomes the light source.

(2) FR Lamps for Indirect Lighting — The use of FR lamps with reflector surfaces downward in industrial or open channel luminaires. This is especially effective in reducing both direct and reflected glare when such luminaires are mounted directly over workers' heads in critical assembly tasks or inspection work. Many such applications of FR lamps have been recommended by lighting engineers to solve critical glare problems.

We agree that for average or moderate dirt conditions, the regular F lamp will provide highest illumination for lowest cost of light. However, there are thousands of smaller installations such as garages, paint or repair shops, storage areas, bare lamps outdoors, etc., where lamps and luminaires are seldom if ever cleaned. In such installations, 50 per cent or more footcandles are obtained with FR lamps at work levels. Therefore, we feel that FR lamps are economically justified for these locations for maximum light at minimum cost.

R. D. BRADLEY:* The authors are to be complimented on having done a fine bit of research; however, it is my experience that trying to estimate or duplicate dirt accumulation without having actual knowledge is somewhat dangerous. In Fig. 3 of the paper, it seems that it might be well to estimate some dirt on the bottom of these lamps. My personal experience indicates that dirt does not accumulate only on the top surface. This would change the percentage figures somewhat. The authors have mentioned this in their text, but did not attach numerical values to it in their calculations.

The glass sleeve idea for approximating dirty lamp conditions undoubtedly could represent one set of atmospheric conditions. I would like to urge the authors to do more research along this line to discover the type of sleeves which could be used for other atmospheric conditions in various types of luminaires.

In actual practice, of course, the luminaires accumulate dirt in a manner which is much more difficult to predict. Without definite knowledge of fixture dirt and ceiling dirt, the over-all maintenance factor is difficult to estimate.

The authors are to be complimented on their approach to these problems, as they have opened new lines of study which I hope will be followed by themselves and others.

C. N. CLARK AND N. F. MEYER:** We are glad to hear that our photometric data are in general agreement with those of Mr. Clark. It is not surprising, of course, to find disagreement on the tests of direct-indirect units. In these, the gain or loss in utilized light resulting from switching from F to FR lamps is strongly affected by the ratio of upward to downward flux; and in tall, narrow (J) rooms, by the fraction of the luminaire output emitted in zones near 90. Mr. Clark's coefficients of utilization for F lamps suggest that the luminaire he tested had a somewhat greater ratio of upward to downward flux than the luminaire on which our Table II data are based. We believe his coefficients for FR lamps include a factor of approximately .87 to account for decreased light output of FR lamps. To be comparable with our Table II data, they should be divided by .87, with the following results:

	CLARK DATA		AUTHORS' DATA	
Lamp Type	F	FR	F	FR
J-Room	.22	.31	.27	.33
A-Room	.66	.76	.66	.74

Mr. Clark's results suggest greater gains in utilization factor for FR lamps *vs.* F lamps than do our data. This is a reasonable result if his luminaire did, in fact, have a greater ratio of upward to downward flux.

We agree that FR lamps should find a wider application in specialized uses rather than in general lighting luminaires. Coves, valances and showcases are good possibilities, as well as the "indirect" positioning of FR lamps behind louvers or diffusers for improved brightness uniformity in large-area luminous elements.

For the ceiling-mounted, bare-lamp channel we tested, our method of testing and calculation of utilization factors accounts for the ceiling reflectance and light-trapping between ceiling, lamps and channel. However, we did not use similar methods for the direct-indirect luminaire. Therefore, our data on this unit would apply only for stem-mounting at an appreciable distance below the ceiling, as Mr. Anderson suggests. The two additional applications of FR lamps suggested by Mr. Anderson are undoubtedly worthwhile ones, but these possible limitations should be considered:

(1) In cove lighting, aiming FR lamps at the ceiling would tend to offer advantages in uniformity of ceiling and upper-wall brightness, and system efficiency (under clean conditions). However, with FR lamps aimed upward, light output of the system would tend to fall off at a considerably faster rate than with regular F lamps because of the tendency for dirt to accumulate mostly on the bright (upper) side of the FR lamps.

(2) The use of FR lamps aimed upward in industrial or bare-channel units would undoubtedly tend to offer some reduction in direct and reflected glare. However, if the lamps are close to a luminaire reflector or high-reflectance ceiling, these surfaces would tend to develop high brightnesses that may be nearly as troublesome in some applications as the brightness of regular lamps. Regular lamps used in luminaires with well-designed reflectors, louvers, or diffusing bottoms appropriately selected for the application would, in many cases, be at least as efficient, comfortable and economical as indirect positioning of FR lamps in simpler lighting units.

We question Mr. Anderson's estimate that FR lamps would deliver 50 per cent higher illumination in typical small, poorly-maintained installations. Our data (extra-heavy dirt conditions, Table V) indicate a 30 per cent increase in maintained illumination, for a closed-top industrial luminaire whose reflector has depreciated to 20 per cent reflectance, in a C room with a 30 per cent ceiling and 10 per cent walls. This represents very poor maintenance. The maximum possible gain in illumination would result when FR lamps were used in a tall, narrow black room. In this case, the gain in illumination *directly below the lamp* would be in direct proportion to its increase in candlepower compared to a regular F lamp — a value of about 60 per cent. Since such extreme conditions are never encountered

*Day-Brite Lighting Inc., St. Louis, Mo.
**Authors.

in general lighting practice, we feel that the value of 30 per cent is more realistic as a maximum possible gain than is 50 per cent.

In Fig. 3, we attempted a simplified schematic illustration of the effect of FR lamp light distribution under clean and dirty conditions. We realize that it may have been over-simplified by omitting the effect of dirt on the bottom of the lamps, as Mr. Bradley points out. Of course, in our photometric tests, the "dirty sleeves" used over the lamps simulated accumulation of dirt on both top and bottom. The amounts of upward and downward light thus absorbed are indicated in the third line of Table I.

The unpredictability of dirt accumulation on lamps, luminaires and room surfaces is well known, and unfortunate. It seems likely that while the *absolute* values of maintenance factor may vary over a great range under field conditions, the *relative* values of maintenance factors for F *vs.* FR lamps would be more consistent. Therefore, we feel that such comparative values as those in Table IV are adequate for broadly predicting the likely advantages or disadvantages in lighting results and costs of F *vs.* FR lamps used in the various luminaires tested for a wide variety of applications. We agree that for specific installations where conditions depart appreciably from those we assumed or tested, either laboratory or field tests under specific conditions would be needed to obtain precise comparisons.

Dressing Up a Store

The usual problem of competition from neighboring stores in a shopping center sent the owner of Groff's Women's Apparel, Toledo, Ohio, to lighting engineers to find a way to make his store stand out.

Various techniques were used. First, the dress salon at the rear of the store was made a focal point by use of a dropped ceiling and higher levels of general illumination. Eight wedge-shaped cavities in the ceiling each use two 48-inch and one 24-inch fluorescent lamps, shielded by vinyl plastic sheet rolled into place on wooden framing strips. Recessed eyeball units around the perimeter help highlight garments.

In the center of the store, four direct-indirect suspended units are located over merchandise on tables. The dress rack is lighted by a valance unit, mounted far enough out to allow light from the continuous row of fluorescent lamps to display all the garments. Showcases are lighted from a row of 150-watt recessed units located over the front edge of the cases.

Behind the showcases, merchandise on open shelves is lighted from a saw-tooth recess cut into the ceiling, with two-lamp 48-inch fluorescent channel at the apex of the recess. Shielding for this is provided every four feet with wooden strips cut to fit the recess.

Lighting designed by Clifford Crookes and Roy Coss, Toledo Edison Co., Toledo, Ohio.

DO move cars back from the front string of lights, so that grillework shows to advantage.

DON'T use lamps that are too small or strings that are not straight. Here lamps are improperly spaced, cars located too far forward.

AUTO DISPLAY — Part II

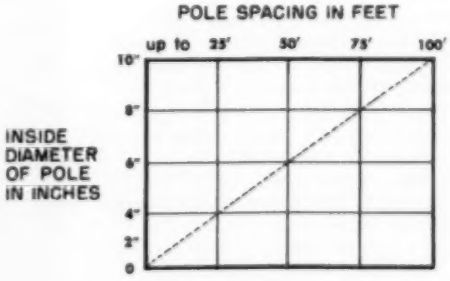
Principles of selling do not change with the age of an automobile, but conditions under which the sale takes place do. New cars are usually displayed indoors with relatively few samples, each of which can be highlighted. Used cars are generally herded together in outdoor lots and lined up in rows. The techniques of lighting for new car display were described in the February issue of IE; and here the treatment for trade-ins is given.

By JAMES F. FINN

USED CAR lots — sometimes strung out, one after another, on heavily travelled thoroughfares — do about 60 per cent of their business after dark. Obviously, lighting is of paramount importance to used car dealers desiring volume business.

Good lighting should start at the perimeter of the lot. If perimeters are well lighted to a depth of 25 feet, lower levels will be adequate for the interior, off-the-street areas. Proper placement of the displayed cars at the perimeter should be combined with location and number of lighting units to achieve maximal effect. Types of equipment commonly used are string lights, floodlights and spotlights.

String lights, almost a symbol for used car lots, are economical from maintenance and installation standpoints. They should be wired for a minimum of 200-watt lamps on 30-inch centers, 1200 watts per circuit, mounted 12 feet from the ground. Rows should be spaced 20 feet apart, except between first and second rows, where 25-foot spacing will permit the displayed cars in the front row to be set



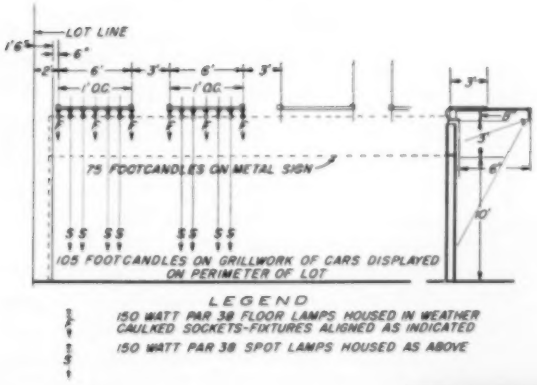
POLE spacing for string lights.

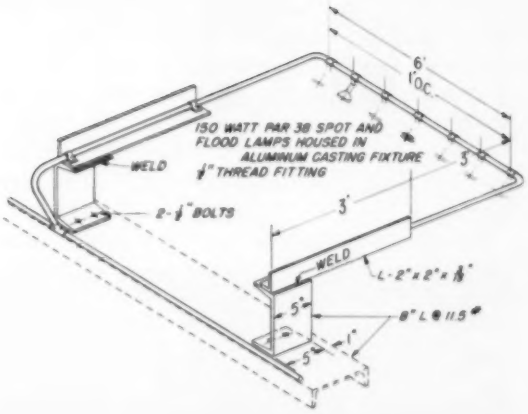
Based on a paper presented at the Great Lakes Regional Conference of IES, June 23-24, Rochester, N. Y. AUTHOR: The Detroit Edison Co., Detroit, Mich.

DO aim floodlights on front row of cars. Floods can be used in combination with string lights as here.

DON'T locate floodlights and cars so that the latter are in darkness.

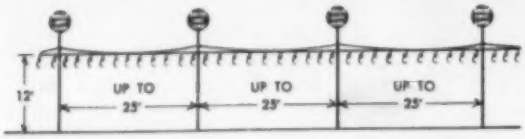
Used Car Lots



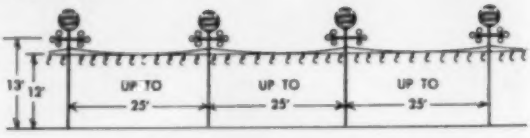


BRACKETS extending out over the sidewalk, mounted at a height of 12 feet, use seven 150-watt lamps each on 6-foot spacing. Compare the effect with that of the used car lot in the background, where string lights are mounted over the tops of car hoods. Drawings above show plan and isometric views of brackets. Four spotlights directed toward grillework provide 105 footcandles. Three floods are directed toward the sign for 75 footcandles.

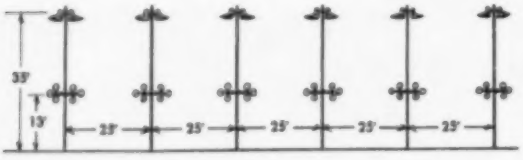
Techniques for General and Front Row Lighting . . .



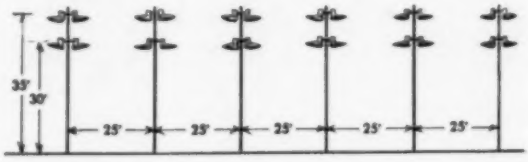
STRING LIGHTS provide about 20 footcandles on the front row of cars plus general interior illumination.



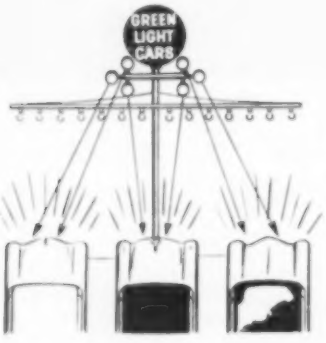
SPOTS and STRING LIGHTS provide 500-1000 footcandles on cars adjacent to each pole.



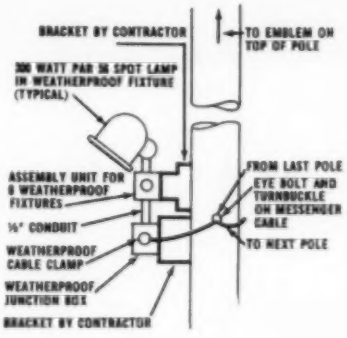
SPOTS and FLOODLIGHTS accomplish the same front row lighting of 500-1000 footcandles plus good interior illumination of lot.



ALL FLOODLIGHTS deliver 60 footcandles to front row of cars. Open-type fixtures with 1500-watt PAR52 lamps are mounted on two arms.



SPOTLIGHTS for merchandising. Six units on each pole, aimed as shown at left, can highlight three cars. Assembly of "merchandising" spotlighting on pole is as shown at right.


BRACKET BY CONTRACTOR
TO EMBLEM ON TOP OF POLE
300 WATT PAR 36 SPOT LAMP IN WEATHERPROOF FIXTURE (TYPICAL)
ASSEMBLY UNIT FOR 8 WEATHERPROOF FIXTURES
½" CONDUIT
WEATHERPROOF CABLE CLAMP
WEATHERPROOF JUNCTION BOX
BRACKET BY CONTRACTOR
FROM LAST POLE
EYE BOLT AND TURNBUCKLE ON MESSENGER CABLE
TO NEXT POLE

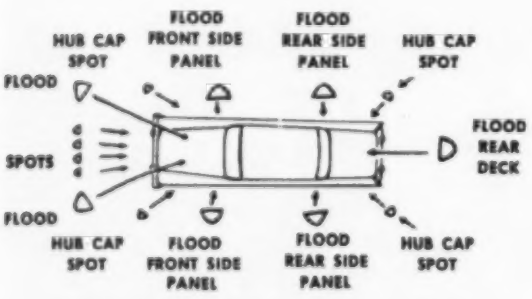
back approximately 5 feet for proper grillework lighting.

Messenger cable and turnbuckles should be used for all string lighting. Quarter-inch extra-high strength galvanized messenger strand with a ¼-inch turnbuckle will be adequate for any lot with up to 100-foot spacing between poles. String light poles should be 20 feet long, sunk 5 feet in the ground. Inside diameters can vary from 4 to 10 inches depending upon the distance between poles.

Spots and floodlights are also standard and effective types of equipment for used car lots. In localities where municipal regulations permit lighting units to extend out over the sidewalks, spot and floodlamps on brackets can produce up to 105 footcandles on the front row of cars. Brackets can use seven 150-watt lamps each and extend 6 feet beyond the sidewalk line.

If such an arrangement is not permitted, the front row of cars should be placed at least 5 feet back from the sidewalk and a sufficient number of spotlights should be aimed on the front grillework.

. . . and for Feature Display



SPECIAL display lighting for featured car.

Recommended Illumination Levels — Used Car Lots

Location	On Grillework Footcandles	General Footcandles
Highly competitive	500-1000	40
Medium competitive	100-500	20
Less competitive	50-100	10

PROPER alignment, positioning and spacing of cars, along with light surfaces for the lot and an adequate number of proper light sources, will assure good lot lighting.

By using six 300-watt PAR56 spots on one pole, sufficient front row lighting can be achieved for three car spaces per lighting pole, providing 500 to 1000 footcandles on the grilles. If floodlights are used for perimeter lighting, they too should be aimed to highlight the chrome.

In creating special displays, floodlights and spotlights can be added in an overhead canopy to set off displays on a corner or center site, to direct attention to a particular car.

Wiring should be planned to allow for future increases in lighting levels, as with the use of the 500-watt PAR64 lamp. Voltage drop should not be more than 5 per cent from service entrance to the most distant lamp on the lot (this factor should be included in the contractor specifications). Convenience outlets should be placed every 50 feet for battery chargers, trouble lights, etc. All outlets should be grounded.

Time-clock controlled switching can be installed which will automatically turn off the main lights when salesmen have left for the night. This leaves on the front row and sign lighting until traffic is at a minimum; then all lighting is turned off, except that needed for protection.

Concrete is best for lot surfacing, but is also more expensive. Gravel or crushed stone has a relatively low cost, but is not as durable or as comfortable to walk on and requires considerable upkeep. Asphalt with marble chips, white limestone or glass beads is preferred. Black top surfacing absorbs about 90 per cent of the lighting.

FORECAST for the Future? Cantilever ceiling over the open used-car display is accomplished by the use of sheet plastic on the under side and translucent fiber plastic on the top of the ceiling area. Daylight filters through to highlight the display during the daytime. Mounted inside the ceiling are rows of lamps fitted into reflectors so that at night the entire ceiling remains luminous and provides the general lighting for the used car display. To accent the cars in the front row, spotlights are mounted in the retaining wall and also overhead.

Applying the principle of highlighting the front row of cars, Harris Oldsmobile, Whittier, Calif., supplies 80 footcandles maintained at the perimeter of the lot. Interior areas have a level of 20 footcandles. This is accomplished by 37 1500-watt clear incandescent lamps in open porcelain reflectors, mounted at a height of 20-25 feet, three or four per pole. Eight of the poles have, in addition, four 300-watt PAR56 floodlamps mounted at 15 feet. The asphalt-surfaced lot is about 22,000 square feet in area.

Lighting was designed by T. O. Furby, Montebello District, Southern California Edison Co.

TWO milj ENTRIES

Applying the Principles of Outdoor Auto Display

Two installations for lighting outdoor car lots, entered in the Southern California Section's contest for My Most Interesting Lighting Job last year, demonstrate how some of the principles expounded in the preceding article are being successfully applied.

New as well as used cars are displayed at Snavely-Langford, Compton, Calif., where the 76- by 123-foot cemented lot blends with the interior showroom as an integrated unit. The light walls at the rear and sides of the lot add to the illusion of an outdoor display room.

A total of 44 porcelain enamel reflector floodlights with 1500-watt lamps are mounted at a height of 20 feet on poles spaced 24 feet on centers at the front and 38 feet at the sides. Maximum maintained illumination level is 100 footcandles, minimum is 10.

This installation was designed by Melvin V. Paul, Compton Division, Southern California Edison Co.

Visionics Field Laboratory

By BENJAMIN GOLDBERG
ROBERT S. WISEMAN

Visionics is a study of vision aided by electronics and includes the entire domain consisting of the irradiating source, the atmosphere, the target and background, the image converter and/or intensifier viewing device, the eye and the human response.

ONE OF THE important missions of the United States Army Engineer Research and Development Laboratories, Fort Belvoir, Va., is to develop night vision equipment for the Army. In the process of fulfilling this mission, a considerable amount of night-time field work in searchlight testing, viewing devices evaluation, and vision research had to be performed. In order to get quantitative information under field conditions, a visionic system outdoor laboratory was established. This laboratory has been automated so that various tasks can be accomplished with the least difficulty, and atmospheric conditions present during the test can be measured. Functions such as searchlight photometry, analysis of viewing systems, and atmospheric optics data collection can be performed quickly and accurately with this facility.

The essential features of the visionic system laboratory consist of the Operations Building (Fig. 1) with Control Room and Goniometer Room, Range and variable Background.

Operations Building

Control Room — The control room (Fig. 2) has the following facilities:

(1) A console containing the recorders and indicators for the remotely located instruments, control switches for remote control of instruments and variable background, radio and telephonic facilities for communicating with all parts of the range.

(2) Recorder rack for simultaneous recording of operating current and voltage of searchlight source, intensity distribution of the beam, and indicator marks for goniometer orientation.

(3) Portable instruments which are available when required. These include: low level illumination and brightness measuring devices and reflectometer, atmospheric measuring instruments and meteorological instruments.

(4) Observation area (Fig. 3) for use of project engineers when evaluating optical or visionic (vision by the aid of electronics) devices.

Goniometer Room — The goniometer room (Fig. 4) contains a 10-foot diameter table which is at floor level and can support a standard 60-inch searchlight on wheels. This table can be tilted in the vertical through ± 6 degrees and rotated through an angle of 30 degrees. Vertical tilt is

A paper presented at the National Technical Conference of the Illuminating Engineering Society, August 17-22, 1958, Toronto, Ont.
AUTHORS: Electrical Engineering Dept., U. S. Army Engineer Research and Development Laboratories, Ft. Belvoir, Va.

Figure 1. Operating Building consisting of control room, goniometer room and machine shop. Transmissometer receivers are at left.

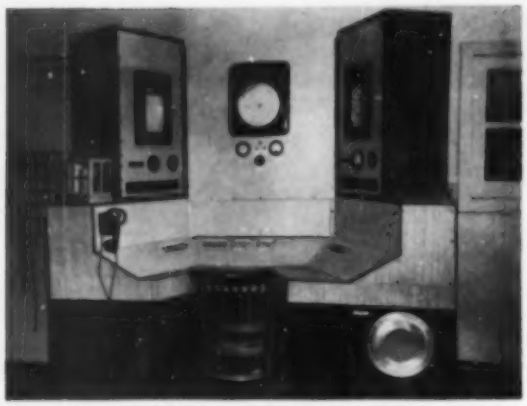


Figure 2. Control room console with switches for control of target, background, transmissometer and weather instruments and recorders for continuous data recording.

Figure 3. Observation area of control room of operations building with small viewer in place to observe target and background located at the far end of the range (3144 feet) visible to the viewer's right and between a trailer-mounted control box and window partition.

Figure 4. Goniometer room with experimental horizontal carbon arc 60-inch searchlight on 10-foot goniometer table.

measured by an optical lever system with a 20-foot path length. The horizontal rotation is indicated on a dial next to the goniometer, and 0.1-degree interval pulses are transmitted to the intensity indicating recorder located in the control room. Vertical tilt is achieved by mechanical means but the horizontal rotation can be accomplished by either mechanical or electrical drive.

A-c (60 cps and 400 cps) and d-c power, compressed air, water, and communication channels to control room are available in the goniometer room.

Range

The range is 6760 feet long. The first 3144 feet is used for most of the work. This 3144-foot range (Fig. 5) is a level, graded strip of bare earth, 200 feet wide. It is bounded by the control and goniometer rooms at one end, the variable background at the other, trees on one side, and widely spaced buildings on the side. Beyond the background, the range depresses 80 feet and then gradually rises to form a wooded hillside. An area on the hillside, level with the goniometer, was cleared to provide access for military vehicles used in visionic studies. This area is approximately 6760 feet from the center of the goniometer.

The 3144-foot range is equipped with ten equally-spaced junction boxes located along the side of the path from control room to the background with one junction box at the background. Fourteen pairs of wire inter-connect these junction boxes with the control room so that power, communications, and instrumentation information can be transmitted. The boxes have been surveyed so they act as range markers indicating the distances from the center of the goniometer.

Transmissometer receivers are installed on 10-foot towers located beside the control room. Transmissometer projectors are installed on 10-foot towers located beside the background at 3144 feet and beside the cleared area at 6760 feet (the installation of the projector at 6760 feet is not yet operable). Temperature and dew point instruments are located beside the background and also outside the control room. An anemometer is mounted on the roof of the control room building. Other instruments which have been listed as being in the control room are used on the range as required.

Variable Background

In order to provide a set of reproducible field situations, an artificial background (Fig. 6), which can be varied in reflectance, was constructed at one end of the 3144-foot range. Reflectance variation can be accomplished since the background consists

Figure 5. View of range taken from one of the junction boxes (at right) and looking toward the background.

of twelve vertical equilateral-triangular cylinders which can be rotated in unison on their vertical axes to form three possible solid area backgrounds of 20 feet high by 50 feet wide. The reflectance of each of the backgrounds so presented is determined by the reflectivity of the paint applied to it. The 4-foot by 5-foot metal panels which form the faces of the cylinders can be removed from the framework and turned around to present a set of three other reflectances. The orientation of the background can be controlled at the background and controlled remotely from the control room.

Military vehicles and personnel are used as targets in front of the background. A special feature of this facility is an 8-foot by 8-foot flat target located 10 feet in front of the background. This target is painted an intermediate reflectance and can be oriented by remote control to be visible (parallel to the background) or invisible (perpendicular to the background). It is used to obtain data on target detection under various atmospheric conditions.

Program of Use

This facility has been used to obtain visionic system information for visible, infrared, and ultraviolet components and systems. For example, searchlight photometry has been performed on the standard 60-inch searchlight and new general purpose 30-inch searchlight, the tank fighting lights utilizing tungsten, mercury compact and capillary, xenon compact and capillary and carbon are sources, and other various types of radiation projection devices. Also, infrared and low level visible visionic viewing devices, *e.g.*, weapon sight (sniperscope), long range surveillance scopes, and binoculars, were tested to determine recognition and detection ranges of these equipments to correlate this field data with predictions obtained from the small scale laboratory research. Initial studies have been made to determine atmospheric effects, *i.e.*, scatter, absorption, and shimmer, on searchlights beams and reflected radiation from targets. These studies are performed in the ultraviolet, violet, and infrared portions of the spectrum. Image intensifier systems

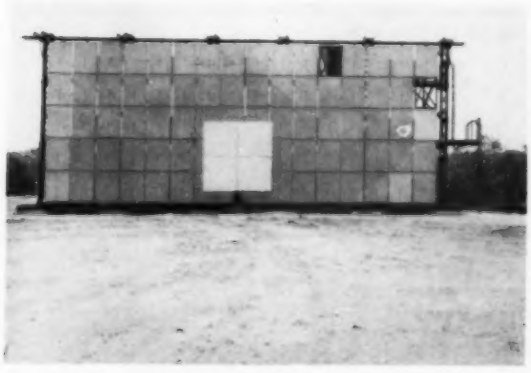


Figure 6a. Close-up of rotating target in front of variable background. Each background panel is 4 feet by 5 feet.

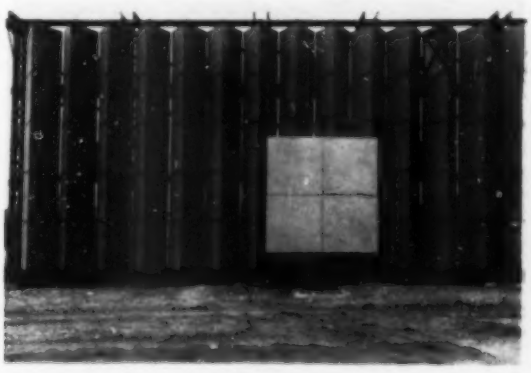


Figure 6b. View of background rotated to show triangular cylindrical shape, construction, operation and different reflectance of each side.

I.E.S. LIGHTING DATA SHEET 10-32

which use the stars for their light source have also been evaluated on this facility.

In order to obtain objective data on visionic systems, it is necessary to observe targets against different backgrounds to determine the effects of contrast and/or determine the threshold condition for detection or recognition. In one night on this visionic laboratory, a viewer can be evaluated objectively for the artificial or real targets against three backgrounds with the controlled illumination and with knowledge of the atmospheric optics conditions. In addition, the same experimental set-up can be repeated at other times during the year, and the data obtained with the modified viewer or new viewer can be compared to the original data. Prior to the development of this unique installation, several nights were necessary for one to move the viewer, instrumentation and targets to various sites in the area to evaluate the viewers under different target-background conditions, and then it would be next to impossible to repeat the experiment or compare the data obtained with any past or future data since the natural backgrounds change with the seasons. Although this laboratory has only recently been completed, tests conducted during its construction have proved the value of being able to establish or easily measure the parameters of the environment.

Acknowledgments

The authors express their grateful appreciation to the present and former members of the technical staff of the Warfare Vision Branch, U. S. Army Engineer Research and Development Laboratories, whose efforts made this facility possible.

DISCUSSION

A. E. Krawcek*: This laboratory is unique in that it contains very complete facilities not only for the photometry of searchlights, but also for their visual evaluation, as well as for evaluations of various viewing systems. Nothing can be more time-consuming than a field test of a searchlight and unless the proper facilities and procedures are established, such tests can be inconclusive. Here we have a thoroughly planned system with complete facilities. This should save a considerable amount of nighttime work and result in a greater degree of accuracy and reproducibility.

It would be interesting to have more of the details of this installation. How are the available power supplies regulated? What is the type of receptor used in the searchlight photometry, and how is the range calibrated? How are the transmissometers calibrated for zero attenuation? To what accuracy can they be held? What are the details of the goniometer and the optical lever system for measurement in the vertical plane?

Benjamin Goldberg and Robert S. Wiseman:* We thank Mr. Krawcek for his comments and interest shown in this laboratory.

The power supplies are not regulated but simultaneous recordings are made of voltage, current, and candlepower and corrections for standard conditions are made. This method of monitoring operating conditions and performance permits operating searchlights from field power supplies to determine variations that may be expected in field use. Because of the wide variety of light sources, it has not been feasible to equip this facility with the necessary variety of regulated power supplies.

The receptors used in the photometry are color corrected—barrier layer cells for the high level visible. Other devices, *e.g.*, aminco photometer, luminous button photometer, and MacBeth illuminometer, are used when more sensitivity is required. These cells and instruments are calibrated using standard lamps and proper care is taken to standardize the leads and recorders, also.

The transmissometers are calibrated as recommended by the manufacturer and the National Bureau of Standards. In addition, a portable transmissometer has been designed and built at the laboratory and this instrument, which directly measures the transmission between two retrodirective reflector positions, is also used to calibrate the installed transmissometers.

The vertical tilt of the goniometer table is measured by a system of light source, mirror, and scale similar to a galvanometer. The light source is mounted on the ceiling and the beam is reflected from a mirror on the goniometer table to a scale on the ceiling.

*Crouse-Hinds Co., Syracuse, N. Y.

*Authors.

Committee Lists in April

A revised listing of the Standing, General, Task and Technical Committees of IES for the year 1958-1959 will appear in the April issue of Illuminating Engineering.

INSTALLATION AT PHILADELPHIA ELECTRIC CO., 1000 CHESTNUT ST., PHILADELPHIA, PA.

Lighting a Load Dispatch Room

LIGHTING OBJECTIVE: To provide a uniform, high level of illumination on load dispatch boards and on desks and instruments.

GENERAL INFORMATION: Fig. 2 is a plan view of this large dispatch room. Height from floor to metal pan ceiling is nine feet. Colors and reflectances of major room surfaces are:

ceiling	white	80% RF	dispatch boards	green	17% RF
floor			desks		
27-inch strip			tops	light gray	35% RF
adjacent to walls	white	56% RF	sides	light gray	14% RF
central portion	pebbled gray	35% RF			

INSTALLATION: Fig. 2 shows the locations and designations of the luminaires, all of which are recessed in the metal acoustical ceiling. The average level of illumination on the desk tops is 132 footcandles. The illumination and brightness values on the dispatch boards are as follows:

Distance from Ceiling	Footcandles	Footlamberts	Distance from Ceiling	Footcandles	Footlamberts
12″	73	12.4	60″	98	16.7
24″	83	14.1	72″	92	15.6
36″	88	14.9	84″	89	14.9
48″	97	16.5	96″	77	13.1

(over)

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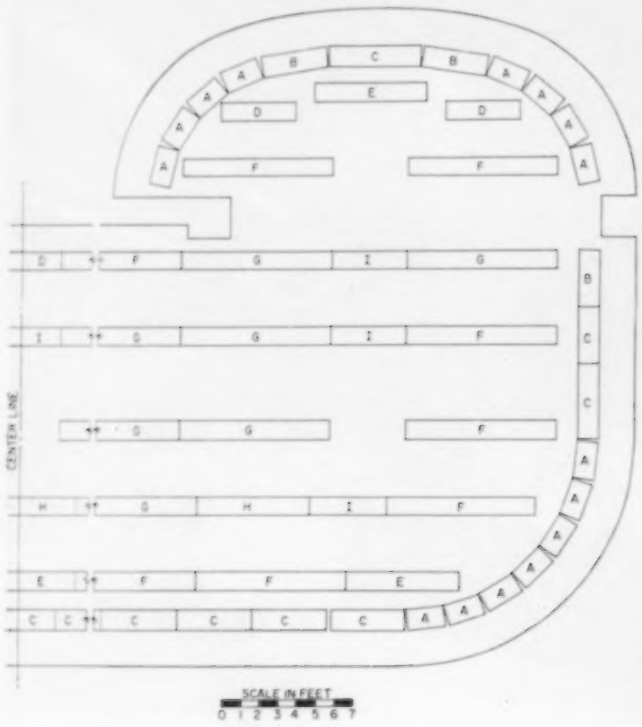

Figure 2. Plan view of dispatch room (only half shown). Luminaires are as follows:

A—Holophane Co. No. 102156-1 equipped with two 24-inch T-12 fluorescent lamps.

B—Holophane Co. No. 102156-2 equipped with two 36-inch T-8 fluorescent lamps.

C—Holophane Co. No. 9012-4 equipped with two 48-inch T-12 slimline fluorescent lamps.

D—Miller Co. No. ST53-FH-4M with Holophane No. 6016 lens and equipped with three 48-inch T-12 slimline fluorescent lamps.

E—Same as D, except No. ST53-FH-6M, equipped with three 72-inch T-12 lamps.

F—Same as D, except No. ST53-FH-8M, equipped with three 96-inch T-12 lamps.

G—Same as D, except No. ST52-FH-8M, equipped with two 96-inch T-12 lamps.

H—Same as D, except No. ST52-FH-6M, equipped with two 72-inch T-12 lamps.

I—Same as D, except No. ST52-FH-4M, equipped with two 48-inch T-12 lamps.

Brightnesses at other locations are:

ceiling	37 fL	desk	
floor		tops	45 fL
27-inch strip	70 fL	sides	8 fL
central portion	43.7 fL		

Lighting designed by Calvin W. Rudolph and William H. Johnson, Philadelphia Electric Co., Philadelphia, Pa.

Lighting data submitted by James R. Rodisch and George T. Anderson, Jr., Philadelphia Electric Co., Philadelphia, Pa.

Published by the Committee on Publications of the Illuminating Engineering Society, 1860 Broadway, New York 23, N. Y.

Controlled Fluorescent Reflector Design For Sharp Cut-Off and Uniform Distribution

By DOMINA EBERLE SPENCER

As LONG as a compact incandescent filament was the source of light, luminaires could be designed assuming a *point source* and their characteristics could be adequately described in terms of concepts associated with a cone of light *diverging* from the point source. The degree of control obtained in incandescent street lighting was handled satisfactorily in terms of these familiar concepts.

The recent development of *very bright fluorescent lamps of small diameter*[1,2] has made possible the design of fluorescent luminaires which produce a controlled distribution of light. Fluorescent lamps of this type have the following inherent advantages:

(1) By suitable reflector design, all light from the fluorescent luminaires can be directed below a *chosen cut-off plane*.

(2) Design for *uniformity* is possible *with a single lamp* and is more effective than designs employing many lamps packed tightly together. Superior performance and more efficient utilization of energy result.

The design of controlled fluorescent luminaires requires the recognition of two basic characteristics of the fluorescent lamp:

(a) The *cross section* of the fluorescent lamp is finite and must be treated as such in the design.

(b) The distribution of light received from a fluorescent luminaire must be described in terms of the *converging* light cone.

The length of fluorescent luminaires is so great that they cannot be approximated by point sources at the distances for which the resulting distribution of light is to be calculated. The concepts, such as candlepower distribution, which are based on the diverging light cone lose all validity with long fluorescent luminaires. The distribution received at any point from a controlled fluorescent system must be specified in terms of the *converging* light cone.

The paper describes how controlled fluorescent luminaires can be designed to properly utilize the advantages of the very bright, small-diameter fluorescent lamp. Attention will be given to the design of reflectors and the characterization of the resulting distribution of light. The effect of interflections from transparent and opaque enclosing surfaces and the design of louvers for clear weather and for fog will also be considered.

A paper presented at the National Technical Conference of the Illuminating Engineering Society, August 17-22, 1958, Toronto, Ont.
AUTHOR: University of Connecticut, Storrs, Conn.

Design for Cut-off

Consider the design of a low-mounted system of fluorescent luminaires for illuminating runway or roadway surfaces. Lamps are mounted below eye-level of the observer. The design criterion is two-fold:

(1) Direct glare from the luminaires is to be entirely eliminated.

(2) A nearly horizontal surface is to be illuminated as uniformly as possible.

To satisfy the first criterion, no light from lamp or reflector is allowed to leave the luminaire in directions above the chosen cut-off plane. A schematic drawing of such a luminaire is shown in Fig. 1. The cut-off plane is tangent to the bottom of the lamp. The top of the luminaire eliminates direct light from the lamp beyond the cut-off plane.

The *principal reflector* is designed, Fig. 2, so that no light from the lamp is reflected above the cut-off plane. The reflector contour is the locus of all points such that the line AP tangent to the front of the lamp is reflected into a line PB parallel to the cut-off plane. Thus, the entire cone of light APC is reflected into the cone BPD which lies below the cut-off plane. If the radius of the fluorescent lamp is R and the distance from lamp center to y-axis is a, the equation of the contour[3] can be written parametrically as

$$\begin{cases} x = a + \dfrac{1}{2}\left[y\left(p - \dfrac{1}{p}\right) - 2pR \right] \\ y = 2p\,[a - R\tan^{-1}p], \end{cases} \qquad (1)$$

where $p = \dfrac{dx}{dy}$. The curve is not a parabola but degenerates into a parabola if $R \to 0$,

$$x = \frac{y^2}{4a}. \qquad (1a)$$

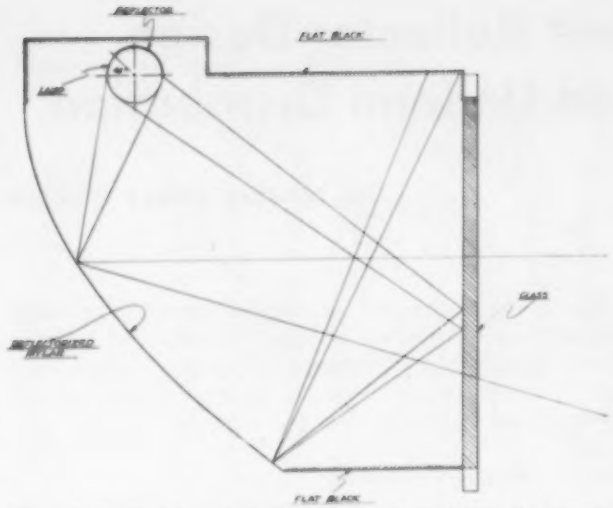

Figure 1. Reflector contour of luminaire designed for horizontal cut-off plane and low-level mounting.

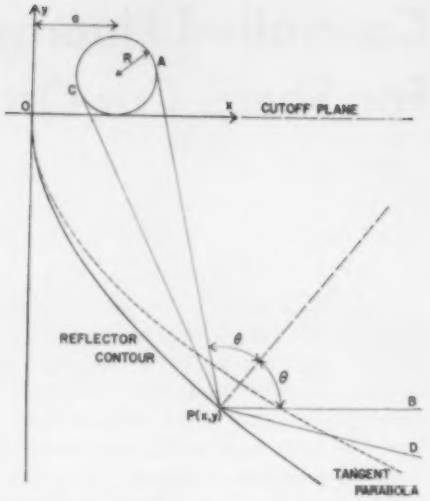

Figure 2. Contour for principal reflector. Solid curve shows non parabolic contour required for horizontal cut-off plane (Equation 1) with lamp of finite radius. Tangent parabola (Equation 1a) is shown as dotted curve.

In Fig. 2, the contour for a lamp of finite radius is shown, as well as the tangent parabola.

In Fig. 3, a family of contours calculated from Equation (1) is shown. To eliminate interflections within the reflectors, they are terminated at the point beyond which interflections would occur.

In runway and turnpike applications luminaires must, of course, be in finite sections set end to end. However, continuous rows frequently extend over a thousand feet. Thus, the simple special case of the infinitely long row of luminaires is of practical significance. End effects will be considered in a following section.

If the luminaire is infinitely long, the inverse-square relation is not valid for any finite distance. Suppose that the reflector of Fig. 1 has a window 10 inches high (extending from 18.5 inches to 28.5 inches above the horizontal) and that cut-off plane is horizontal. Then the light incident on the illuminated surface at distance s from the base of the luminaire is specified by giving the magnitude and direction of a vector D at the point R where the light is received. The vector is defined in terms of a cone of light from the luminaire which *converges* to point R. The vector points in the direction of net flow of energy at R and its magnitude is the number of lumens per unit area incident on a surface perpendicular to the vector at R. The vector D has been called the "pharosage vector" by Moon and Spencer.[4] For any other surface that is illuminated by the entire source for which D is calculated, the number of lumens per unit area incident on the surface is found by evaluating the projection of the vector D along the inward drawn normal to the surface.*

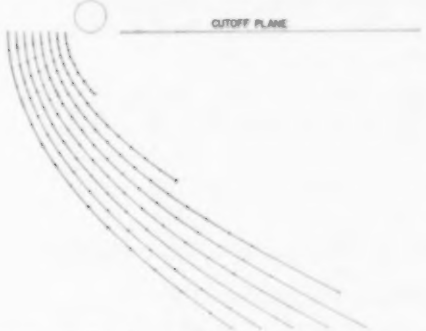

Figure 3. A family of reflector contours for a given size lamp and a given cut-off plane.

The horizontal and vertical components of D, D_h and D_v are plotted in Fig. 4. Light from both lamp and reflector is blocked by the reflector contour for points R close to the base of the luminaire. At distances which are large compared with the mounting height, the horizontal component falls off

*The I.E.S. standards of nomenclature do not include an equivalent term for the "pharosage vector." It is, however, readily measured for a *single* light source at a given point P as follows: Rotate a photocell at the point P until its reading is maximum. The magnitude of D is the number of lumens per unit area incident on the photocell and its direction is that of the inward drawn normal to the surface of the photocell. The "illumination" on a surface which is illuminated by the entire source for which D is calculated is the component of D along the inward drawn normal to the surface.

inversely as the square of the distance, while the vertical component falls off inversely as the first power of the distance. At 100 feet from the base of the luminaire, there is 49 times as much light incident on a vertical as on a horizontal surface.

The large component of D incident on a vertical surface can be utilized in two ways:

(1) If the cut-off plane is rotated slightly below horizontal, major increases in the quantity of light incident on the horizontal result. For example, at 100 feet a rotation through only one degree will nearly double the amount of light.

(2) The large component of D can also be utilized by crowning the pavement as much as possible or by using raised buttons for marking.

It should also be pointed out that the D-vector is useful only in predicting the appearance of a *perfectly diffusing surface*. Runway surfaces which are illuminated and viewed near grazing angles cannot properly be treated as perfectly diffusing. If the specular component is of significance, a more uniform appearance will be found than is implied by Fig. 4. Future investigations are planned on the best treatment of surfaces which depart from the familiar assumption of perfect diffusion.

The extent to which the criterion of sharp planar cut-off is satisfied is shown in Fig. 5. Here, the number of lumens per unit area received on a photocell perpendicular to the radial direction is plotted as a function of angle below cut-off plane. Measurements were made at a 40-foot radius and do not permit the prediction of the polar diagram for other values of r. The concept of planar cut-off is approximated reasonably well.

The second criterion of uniformity over the illuminated surface is fairly well satisfied at turnpike dimensions ($s = 10$ to 40 feet). However, marked non-uniformity is an inherent characteristic of the

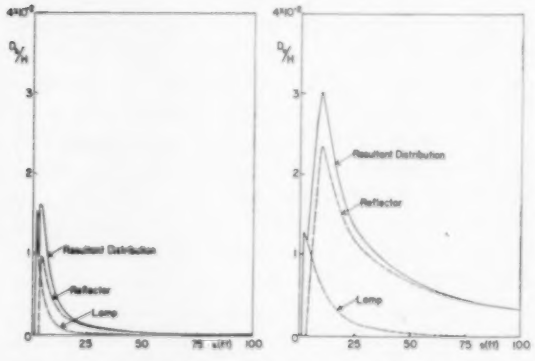

Figure 4. Distribution of light incident on horizontal and vertical surfaces from lumianire of Fig. 1, when mounted with top 28½ inches above illuminated surface, as a function of distance from the luminaire.

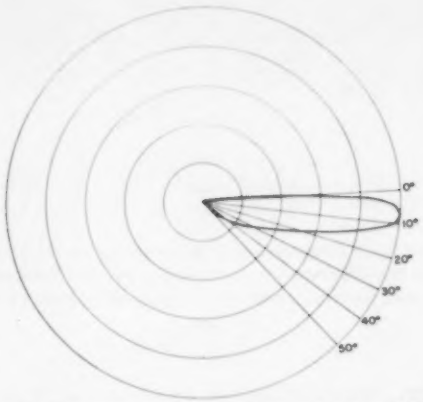

Figure 5. Sharpness of cut-off for luminaire of Fig. 1. Polar plot of light incident on spherical surface 40 feet from luminaire of Fig. 1 as a function of angle below cut-off plane. Because of the large size of luminaire, a single polar plot cannot be used to predict the distribution of light at all distances.

distribution on runways which may utilize distances as much as 100 feet from the luminaire.

Interflections

The designer is faced with the problem of choosing among the contours of Fig. 3. One generally starts with a minimum quantity of light which is to be attained, say, at the center of the runway. How can we get as much light as possible out to the point where the minimum occurs? In order to maximize this minimum, we must maximize the effective width of the reflector contour in the direction perpendicular to the cut-off plane. The number of lumens per unit area received at the center of the runway is directly proportional to the width of the reflector and to the helios** of the lamp as viewed by the reflector. The brighter the lamp and the wider the reflector, the more light is received at the minimum. Note that the use of several equally bright lamps is of no value in a controlled fluorescent luminaire. A single lamp with a reflector ten times its width will produce as much light at the minimum as ten equally bright lamps placed side by side — and with the added advantages of a controlled distribution and elimination of glare above the cut-off plane. Thus, *the width of the reflector in the direction perpendicular to the cut-off plane should be as great as possible.*

**The present I.E.S. nomenclature does not contain an exact equivalent to the word "helios." Helios is a measure of the number of lumens per unit solid angle per unit area *converging* toward the receiver in a given direction. It is the quantity measured by the Luckiesh-Taylor or the Spectra Spot meters. It corresponds to what we see when we look in a given direction. It is always defined in terms of an infinitesimal light cone which *converges at the receiver*. As the word "brightness" is defined by I.E.S., it is identical with "helios" only in the very special cases of perfectly diffusing surface sources viewed in perfectly transparent media.

Figure 6. A luminaire is to be designed to send no light above the 20-degree cut-off plane, yet to illuminate the horizontal surface uniformly, from pole base to cut-off line.

For a given width, the amount of light received from any of the reflectors of Fig. 3 will be the same at any point R for which the entire reflector is filled with an image of the lamp. If point R is moved close enough to the luminaire, the bottom of the principal reflector will no longer be filled. As R comes closer and closer, the effective width of the principal reflector decreases steadily until finally none of it is filled and it ceases to contribute any light to the illuminated surface. For example, in Fig. 4 the entire reflector is filled for all values of s greater than 11 feet and part of the reflector is filled between 3.3 feet and 11 feet. Final cut-off occurs at 3.3 feet. The position of final cut-off and the shape of the distribution in the region of partial cut-off are different for different members of the family of reflector contours. To reduce the peak associated with light from the principal reflector, a larger value of a (Fig. 2) should be used, so that the angle subtended by the lamp at the reflector is decreased. On this basis, one might tend to choose very large values of a and to place the lamp at the front of the reflector close to the window.

Consideration of interflections within the luminaire gives a decisive way to choose the contour.

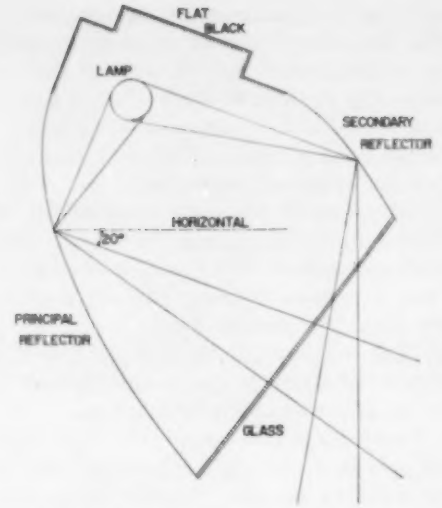

Figure 7. A solution to problem of Fig. 6 employing both a principal reflector from the family of Equation 1 and a secondary elliptical reflector designed using Equation 2.

The reflectance of the window is less than 5 per cent for angles of incidence less than 45 degrees. For angles of incidence greater than 45 degrees the reflectance rises sharply, approaching 100 per cent as the angle of incidence approaches 90 degrees. The most important criterion for the preservation of sharp cut-off is that *interflections must not permit any light to emerge from the luminaire above the cut-off plane.*

(1) For the *position of the lamp* this means that no direct light from the lamp shall be incident on the window at angles greater than 45 degrees, or that the height of the window is approximately equal to the distance of the lamp behind the window, as in Fig. 1.

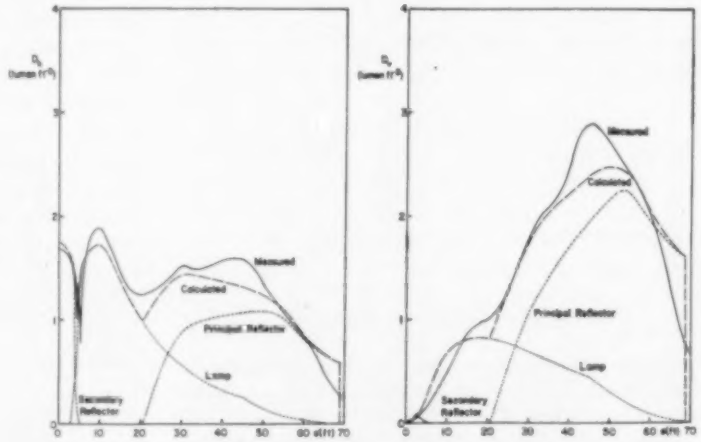

Figure 8. Distribution of light incident on horizontal and vertical surfaces from luminaire of Fig. 7 mounted as in Fig. 6. Theoretical contributions of lamp, principal reflector and secondary reflector are shown along with some experimental data.

(2) For the *reflector*, this means that a sufficiently small value of a and a sufficiently narrow width of reflector must be employed so that no light reflected from principal reflector to window and back to principal reflector can emerge through the window at angles above the cut-off plane. Such stray light should be trapped in the top of the reflector, as shown in Fig. 1.

(3) To trap as much stray light as possible and sharpen cut-off, the entire interior of the top of the luminaire above the cut-off plane should be painted a matt black.

A portion of the light from the lamp can neither be reflected from the principal reflector nor emerge through the window. Some of this light can be utilized by employing a high-reflectance coating on the interior of the lamp.[5] For the angle illustrated in Fig. 1, the use of the "reflector lamp" raises the level of the entire distribution of light by about 16 per cent.

Design for Uniformity

If greater mounting heights are permissible, much better uniformity can be attained. Design criteria are:

(1) No light from the luminaire is to be received beyond one border of the illuminated area.

(2) The incident light on the illuminated area is to be distributed uniformly.

These criteria are suitable for such applications as overhead street lighting and floodlighting.

Consider the example shown in Fig. 6. A luminaire containing a single 8-foot lamp is to be designed with cut-off plane tilted 20 degrees below the horizontal. Mounting height is 25 feet. The horizontal surface is to be uniformly illuminated from pole base to cut-off, which is at $s = 68.7$ feet. Complete shielding is to be provided above cut-off plane.

A solution is shown in Fig. 7. The principal reflector is a member of the family shown in Fig. 3. Practical considerations have imposed an arbitrary limit of one foot to the effective width of the principal reflector. For overhead lighting, a contour as close as possible to the lamp produces optimum coverage. Lamp and reflector are then oriented with respect to the window in such a way as to minimize interflections. The distribution of light incident on horizontal and vertical surfaces as a function of s is shown in Fig. 8. The theoretical distribution for lamp and principal reflector is a reasonable approximation to uniformity except near the pole base.

A *secondary reflector* is now designed to produce an improved distribution in this region. Here sharp cut-off is not ordinarily desired, so an elliptical contour can be employed, as shown in Fig. 9. Foci of the ellipse are at lamp center and pole base. The equation of the elliptical contour is

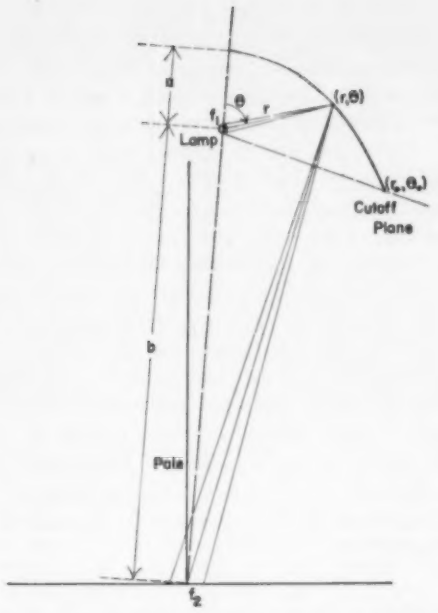

Figure 9. Design of an elliptical reflector to focus a controlled beam of light at base of pole.

$$r = \frac{2a(a+b)}{(2a+b)+b\cos\theta} \qquad (2)$$

where

b = distance from lamp center to pole base,

$$a = \frac{\sqrt{(b-r_o)^2+2br_o(1+\cos\theta_o)}-(b-r_o)}{2}$$

if (r_o, θ_o) are polar coordinates of top edge of win-

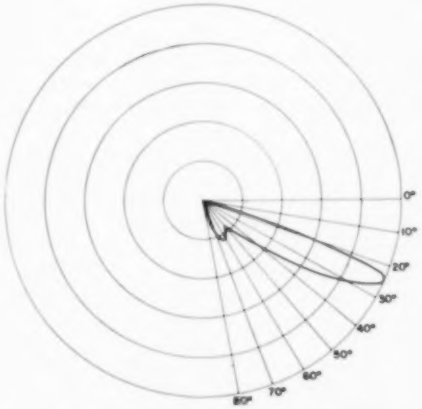

Figure 10. Sharpness of cut-off for luminaire of Fig. 7, measured at 55 feet. The shape of the curve will be different at different distances from the luminaire.

dow. Equation 2 is readily derived from the more familiar equation for an ellipse in rectangular coordinates by transforming from rectangular coordinates to polar coordinates with origin at a focus of the ellipse. The polar form has been found much more convenient for calculating and drawing reflector contours. The effective width of the elliptical reflector is adjusted to give the desired D-vector at the base of the pole. The final result is shown in Fig. 8 together with experimental values. The ratio of maximum to minimum quantity of light incident on the horizontal surface over a distance of 60 feet is only 2:1. Polar distribution in the vertical plane at a distance of 55 feet from the lamp is illustrated in Fig. 10. This curve does not describe the distribution at other distances. Calculations at other points must be made using the converging light cone at R and the vector D. An experimental isolux diagram is shown in Fig. 11 for a single 8 foot luminaire.

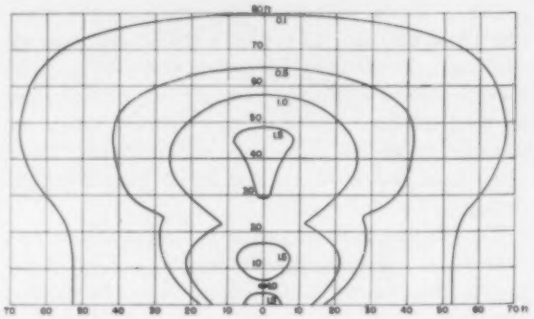

Figure 11. Isolux plot for a single 8-foot luminaire with 20-degree cut-off, Fig. 7.

Louvering

End effects will now be discussed. Controlled fluorescent luminaires are ordinarily constructed in 8-foot sections. End-caps on 8-foot spacing thus provide a certain amount of louvering. If these end-caps are perfectly specular and precisely perpendicular to the cut-off plane, they will reflect no light above the cut-off plane. But as no surface is perfectly specular, end-caps may not be precisely planar or precisely vertical, and there is some stray light in the luminaire. Specular end caps are a source of direct glare. Consequently, all *end-caps which may be viewed by observers* should be painted *matte black*.

In order to reduce the veiling effect of the illuminated layer of fog, intermediate louvers have been suggested for runway and turnpike applications. This problem has been studied in detail elsewhere.[6] The conclusions are that a *moderate* amount of *louvering* (up to 30 degrees) *would not appreciably reduce the veiling effect of the fog* (Fig. 12). If further louvering is introduced the veiling effect of the fog is reduced; however, the apparent advantage is offset visually by an accompanying reduction in the illumination on the runway surface. Thus, *intermediate louvering is not recommended.*

Conclusions

The paper has outlined procedures for designing controlled fluorescent luminaires to provide complete shielding above a chosen cut-off plane and uniform illumination of a chosen surface. Examples have been given which illustrate to what extent the design criteria can be realized. An accompanying paper describes the range of applications to which these design procedures have been applied.[7]

Thanks are due to Robert Cuikay and Lambert L. Montgomery of Sylvania Electric Products, Inc. for assistance in the calculations.

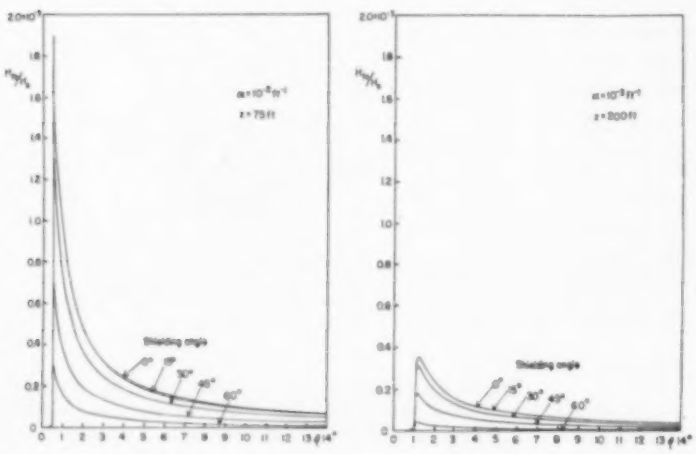

Figure 12. Effect of louvering of runway luminaire in fog. Veiling effect of fog is essentially unaffected by moderate amount of louvering. Strong louvering greatly reduces incident light and defeats purpose of luminaire.
Here α = attenuation of fog,
z = distance from luminaires to center of runway,
ϕ = angle of pilot's line of sight below horizontal,
H_{fo} = helios of illuminated fog layer as viewed by observer at top of illuminated layer,
H_s = helios of source as viewed from center of runway in clear weather.

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DISCUSSION

MERLE E. KECK:* The principles of reflector design for fluorescent lamps using specular materials as set forth in this paper are not new in the lighting industry, but have not been stated in these terms before. It is indeed desirable to see the theoretical optimum expressed as in this paper. In practice, it is seldom desirable to limit the design to the theoretical optimum and make the sacrifices in maximum candlepower and luminaire efficiency that result. I have a few pertinent comments to make, which I believe may clarify certain points.

(1) The very bright fluorescent lamps of small diameter referred to at the beginning of the paper are, I assume, the one-inch diameter 1500-ma type fluorescent lamps. These are no smaller than previous fluorescent lamps and the design of specular reflectors with controlled distribution is not related, timewise, to the development of such lamps.

(2) A reflector of the family of contours defined by equation (1) or Fig. 3 will not produce as much candlepower as a pure parabolic contour, even though it may appear fully flashed to the eye. This sacrifice in maximum candlepower is the price which must be paid for the inclusion of a sharp cut-off plane. The closer the design angle of maximum candlepower is to the design angle of cut-off, the greater will be the reduction in maximum candlepower for a fixed size window opening.

(3) It is seldom true in a practical situation that absolute cut-off is a requirement and, hence, it is seldom necessary to resort to the matte black enclosing surfaces which the author uses. For academic purposes, it would be interesting if the author would tell us the luminaire efficiency of the two designs indicated in the paper.

(4) I find it easier to visualize the calculation of illumination on either a horizontal or vertical surface to be lighted by using Moon's linear source method as published in the second edition of the *IES Lighting Handbook*. Appendix A-29. The cross-sectional polar distribution curve is applicable for one set of angles, and, in the axial direction, the distribution is a tangental sphere. This will give some inaccuracy close to the luminaire, but is sufficiently accurate for most purposes.

(5) I am a little surprised that the author limited her techniques to reflector design in this problem. I believe that a prismatic control surface replacing the plain glass door might have permitted a smaller and more efficient luminaire with equally good control. In two recent practical designs requiring good optical control, namely, a parallel-to-the-curb fluorescent luminaire for street lighting and a mercury vapor luminaire for divided highway lighting, both of which were covered in papers presented at the 1958 National Technical Conference, we have found it desirable to utilize both a specular reflector and prismatic control.

*Outdoor Lighting Engineering, Westinghouse Electric Corp., Cleveland, Ohio.

DOMINA EBERLE SPENCER:* Mr. Keck is to be congratulated on his detailed comments. There are, however, some important concepts developed in the paper which it seems that he has not fully understood.

While Mr. Keck suggests that it is seldom desirable to limit design to the theoretical optimum, my firm belief is that we should always design for the theoretical optimum. For a given size of reflector, the methods of this paper do not require "sacrifices in maximum candlepower." By using reflector contours belonging to the family described in the paper, the *maximum possible quantity of light* (for a given width of reflector) is attained at a *remote point*. There is no sacrifice. In addition, we have the free bonuses of sharp cut-off and control of the distribution of light.

Mr. Keck also discusses "sacrifices in luminaire efficiency." I feel that the word efficiency is so misused in lighting design that Professor Moon and I have suggested that it be eliminated and replaced by the word *loyance*. There is always the preconceived notion that efficiency must be high, the implication being that an efficiency below 80 or 90 per cent implies sinful waste. But, if a luminaire has high efficiency and does not satisfy basic visual criteria, it is of no visual use. Luminaires should be designed primarily to satisfy *significant visual criteria*. Only as a secondary consideration should efficiency enter, and then only in the comparison of alternative proposals, all of which satisfy visual criteria. Generally, one can see better in systems which control the light and give lower efficiency, than in high-efficiency systems characterized by uncontrolled pools of light and glaring non-uniformity. I feel that we should try to maximize the visual benefits rather than the efficiency.

Next let us consider the numbered comments in Mr. Keck's discussion.

(1) Although the lamps employed in the reflectors described in the paper are not smaller in diameter than some previous fluorescent lamps, they are much brighter than previous lamps of the same diameter and much smaller in diameter than other lamps of similar lumen output. The development of these lamps *did* make possible the present development. None of the present applications would have been practicable if larger lamp diameter required larger reflectors for the same amount of control, or if smaller lamp output reduced the quantity of light available. Brighter fluorescent lamps of even smaller size would improve the application potential of controlled fluorescent lighting.

(2) Here, it seems, Mr. Keck has misunderstood the basic design principles of the paper. For the same effective width of reflector, a fully flashed parabolic reflector and a fully flashed member of the family of non-parabolic reflectors would produce exactly the same "maximum candlepower." The difference between the two types of reflectors lies entirely in the sharp cut-off possible with the new type and in the control now possible over the distribution at points close to the luminaire.

(3) It should be noted that the use of reflector lamps salvages part of the light which Mr. Keck fears will be absorbed in the black enclosing surfaces. The efficiency of the luminaires designed from the family of contours of

*Author.

I.E.S. LIGHTING DATA SHEET 13-90

Equation (1) has run from 40 to 55 per cent, depending on the degree of control required. Other methods of design, which retain the advantages of the present designs will permit efficiencies approaching 100 per cent, but these are not yet practical. The black enclosing surfaces are essential if sharp cut-off is to be retained.

(4) Although Mr. Keck prefers to use the approximate calculation procedures suggested by Professor Moon, I find it necessary to use the exact calculation method also found in Professor Moon's work. This latter is a little more difficult to use, but the discrepancies otherwise encountered are significant in the applications of controlled fluorescent.

(5) Some consideration has been given to the possibility of using prismatic glass. However, as reflectors can be designed which take into account the finite cross-section of the lamp, and refractors cannot, use of the prismatic reflectors would certainly decrease the sharpness of the cut-off.

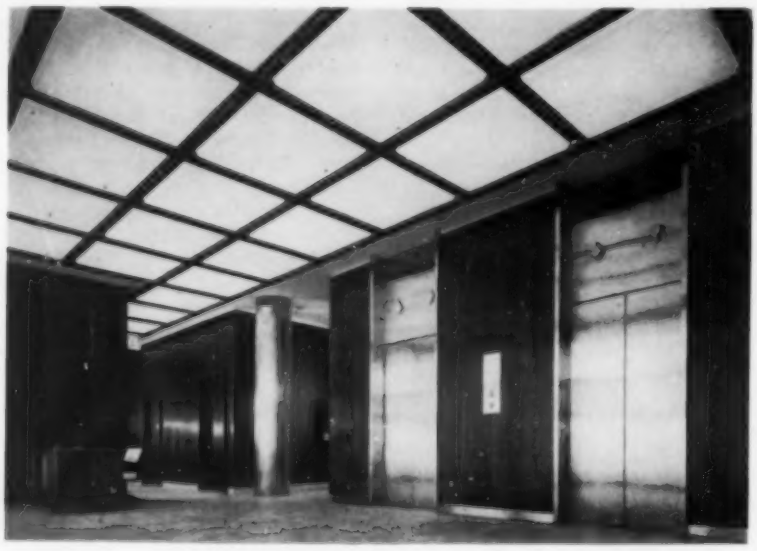
Probably the discrepancy between Mr. Keck's point of view and mine is quite fundamental. He does not seem to feel that much can be done about quality of lighting in outdoor work and concentrates on getting a quantity of light with relatively little attention to how it is distributed. My attitude is quite different. I am dreaming of street lighting, runway lighting and floodlighting which produces the optimum visual environment for nighttime seeing. Accepting the limitation of a dark sky, what is the best field of view for the task at hand? It is not enough to satisfy the present IES Recommended Practice for Street Lighting. We should not be satisfied until we can design lighting which is to outdoor applications what the luminous ceiling is to interior lighting: a realization of the optimum luminous environment.

Luminous Element for Lobby Lighting

A transilluminated ceiling, of 43-inch square convex acrylic plastic diffusers in hinged aluminum frame, provides 45 footcandles after six months operation in the lobby of the five-story office building of the Jewish Federation of Chicago. The hinged frame is supported by steel cross supports which are 48 inches on centers. Fastened to these steel supports are wedge-shaped teakwood baffles, 3 inches deep. The baffles, which match the teakwood paneling in the lobby are permanently fixed to the cross supports, allowing diffusers to be opened and closed without disturbing the baffles.

Above the diffusers are 40-watt T12 standard cool white rapid start lamps, mounted in a grid channel system with the center of the lamps 18 inches above the plastic. They are on 27-inch centers. Brightness of the ceiling varies from 125 to 175 footlamberts.

Photo and data courtesy of Melvin Cohen of A. Epstein and Sons, Inc., Engineers, Chicago, Ill.



INSTALLATION AT GENERAL ELECTRIC CO., MILWAUKEE, WIS.

Lighting a Private Office

LIGHTING OBJECTIVE: To provide functional lighting for the various tasks performed in a private office and to serve as a demonstration of three lighting levels.

GENERAL INFORMATION: This room measures 16 feet by 20 feet. The height from floor to the plastic louver ceiling is eight feet. The ceiling plenum above the plastic is two feet in depth. Colors and reflectances of all major surfaces are as follows:

plenum	off white	70% RF	blinds	light green	39% RF
ceiling panels	"frosty"	25% RF	desk top	light wood	39% RF
ceiling tile	white	75% RF	desk top blotter	green	27% RF
block wall	light green	39% RF	carpet	beige	18% RF

INSTALLATION: One 12-foot by 16-foot Curtis Lighting, Inc. special Strato-Lux lighting system provides three levels of illumination in this office, with 130 footcandles as the maximum. Every

(over)

A.I.A. File No. 31

third row of lamps in this installation is group switched. The Strato-Lux lighting system consists of: 18 Curtis catalog No. 26562-16 wired Curtistrip units, mounted eight inches on center, each equipped with four 40-watt T-12 cool white rapid start lamps; and 48 Curtis catalog No. 9123 two-foot by two-foot CurtiCell plastic louver diffusers. The louver diffusers are made of double layers of vinyl plastic formed to create an eggerate louver bottom effect. The top sheet of plastic is to diffuse the light and reduce specular reflections.

Brightness readings after about 10 months operation were:

ceiling panels		ceiling tile	18 fL
center, straight up	350 fL	wall	25 fL
center, at 45 degrees	220 fL	blinds	25 fL
border, at 45 degrees	100 fL	desk top	50 fL
desk blotter	35 fL		

Lighting designed by Wisconsin Electric Power Co., Special Services (Lighting) Sales Division and William Lowell of General Electric Co., Lamp Department; Installed by Good Electric Co., Milwaukee, Wis.

Lighting data submitted by Ray G. Eigner, Milwaukee, Wis.

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Analogue and Digital Computer Solutions Of Daylighting Problems

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Analogue and digital computers may be employed for the solution of the finite difference equations which describe daylighting and/or lamp-lighting systems. Asymmetrical locations of daylighting sources and the nonuniformity of the outdoor luminance pattern are complicating characteristics which can be treated by this analytical method. An idealized daylighting problem is solved by computers of the two types and the relative features are discussed. Analytical and experimental data for two daylighting systems are compared.

Daylighting Design

Daylight and lamplight are introduced into rooms in order to provide a luminous environment, fitted to the performance of visual tasks by man in a comfortable and effective manner. Lighting design is concerned with the formulation of lighting systems that conform both to the visual and to the economic requirements. In order to evaluate the performance of a lighting system, when it exists only on the drawing board, the illumination and luminance distribution within the room must be predicted. This predetermination of luminous quantities is complicated by the many independent variables (*e.g.*, wall, ceiling and floor reflectances, location and size of light input and room geometry) that define the system.

Both experimental and analytical studies have been performed to provide data and/or analytical representations which allow the designer to predict the illumination and luminance patterns in a daylighted room. Perhaps the most extensive collection of empirical data describing daylighting in rooms has been reported by the Daylighting Research Group[1] of Southern Methodist University. Although great quantities of useful data have been generated by empirical studies, the diversity and dynamics of architectural design prevent, for economic reasons, an exhaustive study of all cases of interest to the lighting designer.

To fill the need for a more flexible source of design data, several analytical methods for the predetermination of luminances in daylighted rooms have been reported, as by Dresler.[2] Some of these analytical methods are characterized by simplifying idealizations that cause the mathematical-model behavior to depart widely from the real situation. The application of the integral equation method to the daylighting problem has been suggested by Spencer and Stakutis,[3] but this method has not developed because the integrals that arise are difficult to solve in closed form.

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The finite difference equations[4] which are derived from the Fredholm integral equation seem to present the most flexible tool for the daylighting problem. Several authors, including Dourgnon[5] (France), Centeno and Zagustin[6] (Venezuela), and O'Brien,[7] have pointed out the adaptability of the finite difference equations to daylighted rooms and outdoor spaces with asymmetrical source locations and reflectance distributions. Dourgnon[5] has suggested that a digital computer be employed to solve the finite difference equations while O'Brien[7] has shown the use of the Luminous Analogue Computer for a room with daylighting.

In order to illustrate the use of this analytical method for daylighting design and, also, to discuss the application of computers, three daylighting systems are analyzed in this paper. The first problem, an infinitely long square section hallway, is so idealized as to be trivial, but was chosen to help explain the details of this analytical method. Problems II and III were chosen to allow a comparison between experimental and analytical data. Some indication of the order of accuracy to be obtained by this method is given by this comparison.

Problem I — Infinitely Long Hallway

A very long hallway of square cross section is lighted by a clear window that occupies the entire north wall, as shown in Fig. 1. Because the window-wall looks toward the north, and the direct solar illumination is incident on the south opaque-wall, the solar luminous-flux that enters the hallway

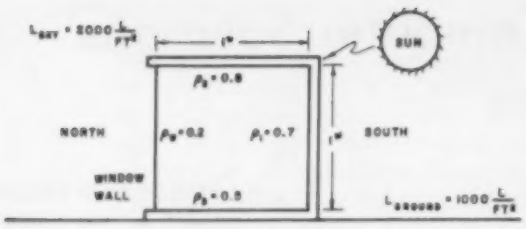

Figure 1. Sectional view of long hallway (Problem I) lighted from ground and sky through a window-wall of 80 per cent transmittance and 20 per cent reflectance.

comes from the ground and sky whose luminous emittances are assumed uniform at 1000 and 2000 lumens per square foot, respectively. The window wall has an 80 per cent transmittance and a 20 per cent reflectance; it is postulated that the transmittance is independent of the angle of incidence and the direction of the transmitted flux is unchanged at the window and the reflected flux is perfectly diffuse at all surfaces of the room. The surface reflectances are as shown in Fig. 1 and the subscripts 1, 2, 3 and W refer to the walls, ceiling, floor and window-wall, respectively.

The finite difference equations which describe the long hallway are as follows, if each surface is lumped as a single element of uniform luminous emittance:

$$\begin{aligned}
(1/\rho_1)L_1 - F_{1\to 2}L_2 - F_{1\to 3}L_3 - F_{1\to W}L_W &= L_{01}/\rho_1 \\
-F_{2\to 1}L_1 + (1/\rho_2)L_2 - F_{2\to 3}L_3 - F_{2\to W}L_W &= L_{02}/\rho_2 \\
-F_{3\to 1}L_1 - F_{3\to 2}L_2 + (1/\rho_3)L_3 - F_{3\to W}L_W &= L_{03}/\rho_3 \\
-F_{W\to 1}L_1 - F_{W\to 2}L_2 - F_{W\to 3}L_3 + (1/\rho_W)L_W &= L_{0W}/\rho_W
\end{aligned} \qquad (1)$$

where:

$\rho_1, \rho_2, \rho_3, \rho_W$ = surface reflectances (dimensionless).

$F_{n\to m}$ = the shape modulus; the fraction of flux (lumens) leaving area A_n which is directly (without interreflection) intercepted by area A_m (dimensionless).

L_1, L_2, L_3, L_W = the average luminous emittances of the surfaces including all interreflections (lumens per square foot).

$L_{01}, L_{02}, L_{03}, L_{0W}$ = the average initial luminous emittances of the surfaces before interreflections (lumens per square foot).

If the luminance pattern in the hallway is to be predicted, the equations are solved for L_1, L_2, L_3 and L_W. Note that L_W is the luminous emittance of the window only with regard to indoor interreflected flux and the actual luminance viewed will be the sum of the indoor and the outdoor luminances.

The coefficients of the total luminous emittances are the shape moduli and the surface reflectances which are independent of the value of the stimuius or input terms on the right hand of Equation (1). This suggests that a single input term L_{0n}/ρ_n should be considered at a time, and the usual flux transfer functions L_n/L_{0n} be computed. A set of these flux transfer functions for the particular geometry and reflectances of the long hallway would allow the computation of the total emittances L_n by superposition. Briefly, transfer functions linking the outdoor and indoor luminance patterns are required for daylighting design.

Another approach to the solution of Equation (1) is to change the form to that of Kirchhoff's node equation.[4] When the finite difference equations are in the form of Kirchhoff's equation, an analogue network which contains all the terms of Equation (1) can be constructed as in Fig. 2. The equivalent circuit or network model, Fig. 2, of the long hallway can be solved by conventional network analysis for L_1, L_2 etc., or an electrical network with parameters of the proper value can be built and the potentials proportional to L_1, L_2, etc. can be measured with a voltmeter. The Luminous Analogue Computer[7] is an adjustable electrical network which is used in this latter manner.

Regardless of whether the finite difference equations or the network are employed, the shape moduli and the initial division of the flux within the hallway must be computed. As shown in Table I, only two shape moduli need be computed be-

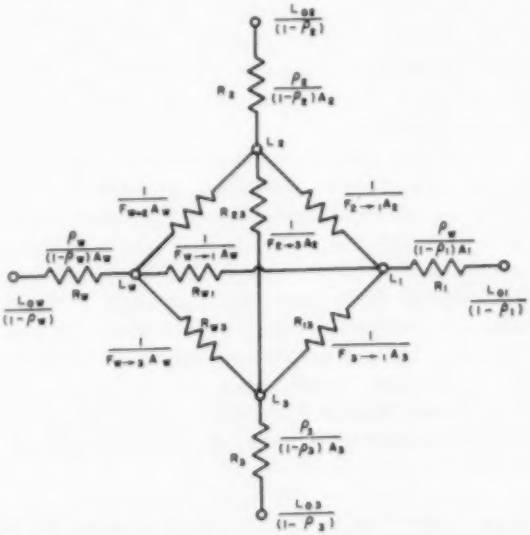

Figure 2. Equivalent circuit or network representation of the long hallway (Fig. 1).

TABLE I — Data for the Analogue and Digital Computer Solution of the Long Hallway as Described in Figs. 1 and 2.

Reflectances:	$\rho_1 = 0.7;\ \rho_2 = 0.8;\ \rho_3 = 0.5;\ \rho_W = 0.2$
Shape Moduli:	
	$F_{2\to 3} = F_{3\to 2} = F_{1\to W} = F_{W\to 1} = 0.414214$
	$F_{1\to 3} = F_{3\to W} = F_{2\to W} = F_{1\to 2} = 0.292893$
Initial Luminous Emittances (lumens/ft²):	
	$L_{01} = 347.94;\ L_{02} = 187.45;\ L_{03} = 234.31;\ L_{0W} = 0$

cause of symmetry. The initial luminous emittances in Table I were computed by the following relationship:

$$L_{0n} = \rho_n \tau_g \left[L_{sky} F_{n\to sky} + L_{ground} F_{n\to ground} \right] \quad (2)$$

where:

L_{0n} = the initial luminous emittance of surface A_n in the room (lumens per square foot).

ρ_n = luminous reflectance of A_n (dimensionless).

τ_g = specular transmittance of the glazing, equal to 0.8 in this problem (dimensionless).

L_{sky}, L_{ground} = luminous emittance of the sky and ground, respectively (dimensionless).

$F_{n\to sky}$ = shape modulus from A_n to the sky, that is, the fraction of diffuse flux leaving A_n which streams toward the sky (dimensionless).

$F_{n\to ground}$ = shape modulus from A_n to the ground (dimensionless).

If the sky and ground luminance pattern were each non-uniform, regions or finite steps of nearly uniform outdoor luminance could be considered by merely including additional terms $L_m F_{n\to m}$ within the bracket of Equation (2). As shown in Table I, L_{0W} is zero because the flux streaming through the clear window is non-diffuse, and the initial inputs L_{0n} to Equation (1) must be diffuse. That is, for the convenience of analysis, the luminous stimuli L_{01}, L_{02}, and L_{03}, which are diffuse fluxes, are employed rather than the non-diffuse window. In this highly idealized problem, the initial and higher order incidences of luminous flux at the room surfaces are postulated to be uniform. The truncation error[4] associated with this postulate can be reduced by dividing the room surfaces into smaller but finite areas for the analytical treatment.

The total luminous emittances L_1, L_2, L_3 and L_W of the long hallway can be computed by solving Equation (1) using the numerical values for room geometry (shape moduli), room properties (reflectances) and luminous inputs (initial luminous emittances) as reported in Table I. By solving the finite difference equations, Equation (1), with a small general purpose digital computer (*i.e.*, the Bendix G-15D) the total luminous emittances shown in Table II were obtained. As an alternate approach to the solution of Equation (1), the equivalent circuit (Fig. 2) of the long hallway was set on the Luminous Analogue Computer. The emittances obtained by this analogue method are also reported in Table II. The percent error of the analogue solution relative to the digital solution is associated with inaccurate settings of the resistances and errors in the voltmeter readings. An average error of one per cent seems to be characteristic of the analogue values. Local and global errors associated with stochastic and/or biased uncertainties in the potential and resistance settings need to be investigated as Spencer[3] has done for the Interflection Method.

Analogue Versus Digital Computers

Some relative advantages and limitations of the application of the Luminous Analogue Computer and a small digital computer like the Bendix to daylighting problems are: (1) the program time, or time to compute the shape moduli, is identical for the two types; (2) the time to place the problem on the Analogue Computer is slightly longer because the parameters (L_{0n}/ρ_n) and $(1/A_n F_{n\to m})$ must be computed and set on the machine, but the shape moduli and reflectances can be fed to the digital computer directly as through an electric typewriter; (3) the characteristic data for a particular daylighting problem can be stored on punched tape, punched cards or magnetic tape on the digital computer, but the input data must be reset manually each time a new problem is placed on the Luminous Analogue Computer; (4) for a particular set of room and input characteristics the solution time for the Analogue Computer is effectively instantaneous, while a relatively slow digital computer like the Bendix takes about ten minutes to solve a room represented by ten surfaces; (5) the Luminous Analogue Computer is, at present, limited to rooms represented by ten surfaces (although it could be expanded easily) while the Bendix G-15D has a standard program for a fifteen-surface problem; (6) synthesis of required luminance patterns in terms of inputs and room reflect-

TABLE II — Comparison of the Total Luminous Emittances of the Surfaces of the Long Hallway (Fig. 1) as Obtained with the Bendix G-15D Digital Computer and the Luminous Analogue Computer.

Machine	L_1	L_2	L_3	L_W
Digital Computer	565.74	487.03	432.79	100.75
Analogue Computer	560	479	431	101
Per Cent Error	+1.02	+1.67	+0.42	−0.25

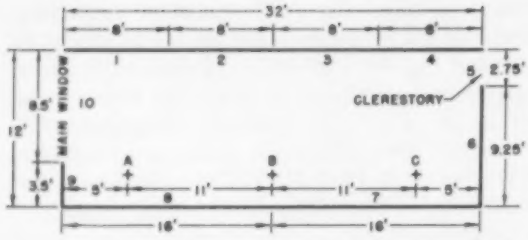

Figure 3. Sectional view of daylighted room studied experimentally by the S. M. U. Daylight Study Project (Reference 1 and Problem II of this paper).

ances is more easily accomplished with the Analogue Computer because the iterative process is aided at each step by the judgment of the operator, but the digital computer is not effectively used if it reads out at each step in the computing process; and (7) the initial cost of the Luminous Analogue Computer is about one per cent of the initial cost of the small digital computers of the Bendix G-15D capacity.

Problem II — S.M.U. Test Room

To demonstrate the use of the Luminous Analogue Computer for a bilateral daylighting problem, the test room employed by the S.M.U. Daylighting Research Group[1] was chosen for analysis. As shown in Fig. 3, the room dimensions are 32-foot width with respect to the fenestration, 64-foot length and 12-foot height. The fenestration consists in a main window which extends 8.5 feet from the ceiling, and a clerestory that extends 2.75 feet from the ceiling on the opposite wall. Both windows extend the entire length of the room. In order to conform to the reflectances specified in reference 1, the following reflectance values were used: ρ walls = 0.7, ρ ceiling = 0.85, ρ floor = 0.3, ρ windows = 0.2.

The programming of the Luminous Analogue Computer for this problem consisted of: (1) dividing the room surfaces into ten surface elements as shown and numbered in Fig. 3, (2) computing the geometrical parameters or surface to surface resistances *(i.e.,* $1/F_{n\to m}A_n$*)* as listed in Table III, (3) computing the surface reflectance parameters *(i.e.,* $\rho_n/(1-\rho_n)A_n$*)* as listed in Table III, and (4) setting the input-flux controls at the main window and clerestory so that the input to the room was 80 lumens per square foot of window area. As shown in Table III, certain surface to surface resistances *(e.g.,* R_{1-2}*)* are infinite because the surfaces lie in the same plane and do not "see" or directly exchange luminous flux with each other.

In order to compare the performance of the network with the empirical data published by the Southern Methodist Daylighting Research Project, the condition of diffuse control at the fenestration or equal sky and ground luminosity was selected. These empirical data are plotted in reference 1 for both the main window and the clerestory or bilateral window.

In Fig. 4, the illumination on the work plane *(i.e.,* 30 inches above floor) is plotted as a function of position with respect to the fenestration and in the middle of the room with respect to the length. The illumination from the main window and clerestory are plotted separately and together. The data points as shown on Fig. 4 were computed from the data contained in Figs. 13 through 18 and from the equation on page 107 of reference 1. The difference between the analytical and experimental values is less than five per cent in all cases.

A value of 80 lumens per square foot for the luminous flux input at the windows was chosen because this is a convenient value to set on the Luminous Analogue Computer. If the input of luminous flux at any window is adjusted by a multiplying

TABLE III — Surface to Surface and Reflectance Resistances for the Test Room as Shown in Fig. 3. Subscripts Refer to the Areas Designated on Fig. 3.

$R_{n-m} = 1/F_{n\to m}A_n$, and $R_n = \rho_n/(1-\rho_n)A_n$

n–m	1-2	1-3	1-4	1-5	1-6	1-7	1-8	1-9	1-10	2-3	2-4	2-5
R_{n-m}	∞	∞	∞	25	3.47	1.18	.245	2.1	.417	∞	∞	25
n–m	2-6	2-7	2-8	2-9	2-10	3-4	3-5	3-6	3-7	3-8	3-9	3-10
R_{n-m}	1.81	.468	.244	2.25	1.38	∞	9.63	.934	.244	.468	4.46	3.13
n–m	4-5	4-6	4-7	4-8	4-9	4-10	5-6	5-7	5-8	5-9	5-10	
R_{n-m}	985	.495	.245	1.18	7.36	5.44	∞	1.65	3.00	7.12	3.36	
n–m	6-7	6-8	6-9	6-10	7-8	7-9	7-10	8-9	8-10	9-10		
R_{n-m}	.292	1.56	1.96	0.83	∞	12.4	1.19	6.35	.420	∞		
Surface	1	2	3	4	5	6	7	8	9	10		
ρ	.85	.85	.85	.85	.20	.70	.30	.30	.70	.20		
R_n	.707	.707	.707	.707	.091	.252	.027	.027	1.45	.029		

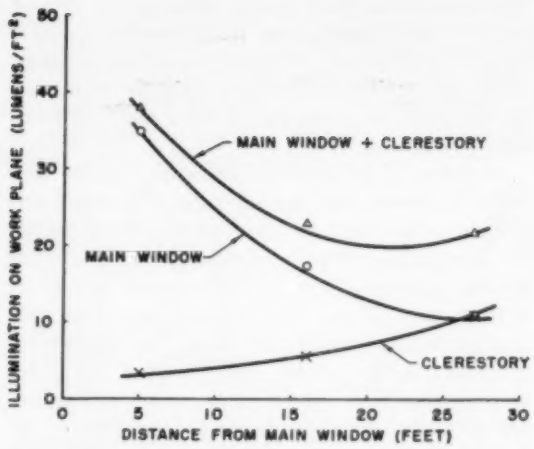

Figure 4. Illumination distribution on work plane and across the room with respect to the fenestration. The solid line was computed from the network, while the data points were obtained from the S. M. U. Study (Problem II of this paper).

factor, all illuminations and luminous emittances associated with that window are simply adjusted by the same factor. For example, if the input of the large window had been 160 lumens per square foot, the illumination on the work plane five feet from the window would be 69 lumens per square foot.

In Fig. 5, the effect of floor reflectance on the illumination of the work plane is shown for floor reflectances of 0, 30, and 100 per cent. These data indicate that the illumination on the work plane at a location 27 feet from the clerestory will be increased 50 per cent when the floor reflectance is raised from 0 to 30 per cent, and will be increased about 400 per cent when the floor reflectance approaches 100 per cent. Because the experimental data of reference 1 are reported for a single floor reflectance of 30 per cent, the calculated data of Fig. 5 cannot be compared to these experimental data.

The total luminous emittance of the ceiling as a function of position with respect to the fenestration is plotted in Fig. 6 with fenestration input and floor reflectance as the parameters. With normal reflectances (*e.g.*, $\rho_{ceiling} = .85$, $\rho_{walls} = 0.7$, $\rho_{floor} = 0.3$), the brightness ratio on the ceiling is about 3 for the input at the main window alone but is reduced to about 2 when the clerestory is added.

When the normal reflectances, as listed above, are used, the maximum brightness ratio in the room is 14 to 1 from the window to the floor. This brightness ratio is reduced to 2 to 1 when the floor is made white. In Fig. 7 the total luminous emittances of all surfaces in the room are reported.

In addition to the illumination on the work plane, the illumination on a plane of any orientation may be computed with the data provided by

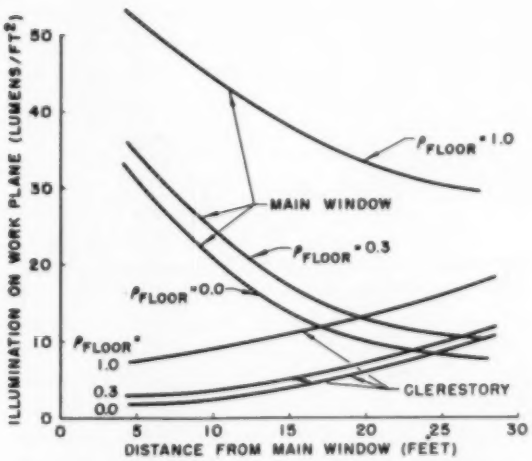

Figure 5. Effect of floor reflectance on work-plane illumination in S. M. U. Test Room (Problem II of this paper).

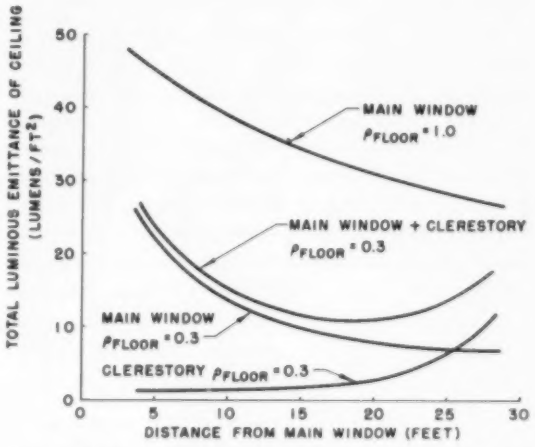

Figure 6. Computed luminous emittance distribution on ceiling of S. M. U. Test Room (Problem II of this paper).

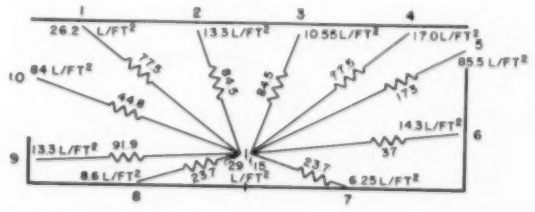

Figure 7. Illumination on a vertical plane at work plane height in center of S. M. U. Test Room (Problem II of this paper).

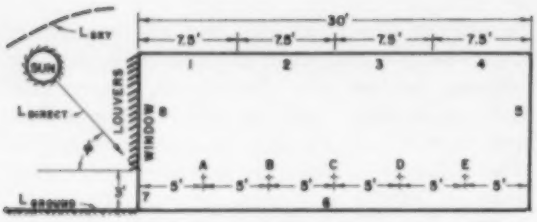

Figure 8. S. M. U. Test Room (Reference 9 and Problem III of this paper) with horizontal louver control. The finite areas used in the network analysis are numbered around the room: ρ ceiling = 0.8, ρ walls = 0.7, ρ floor = 0.3, ρ window (effective) = 0.42.

the network solution. For example, the illumination on a vertical plane looking toward the main window from position B of Fig. 3 is represented by the network of Fig. 7. As shown in Fig. 7, the illumination on the vertical plane at the center of the room at the work-plane level is 29 lumens per square foot looking toward the large window, but only 15 lumens per square foot looking toward the clerestory. These data may also be employed to compute the shadow forming conditions within the room.

Problem III — Daylighting Through Louvers

The finite difference approach may be used to study daylight transfer to a room with louvered control at the windows. The general approach is to treat the louver and room as two separate systems. The network method is first used to derive transfer functions which relate the daylight flux into the room via the louver to the sky, ground, and direct daylight fluxes at the outside plane of the louver. Once the transfer functions for a particular louver system have been determined, the total daylight flux transferred can be computed for all sky, ground or direct input conditions. With the total daylight flux coupled through the louver used as a luminous input, the luminance pattern within the room may be computed with the aid of the Luminous Analogue Computer.

In order to demonstrate the utility of the network approach for the solution of louver-room problems, the room with horizontal louver control for daylighting which was studied empirically by Griffith[9] was chosen for analysis. As shown in Fig. 8, the room is 30 feet wide with respect to the window, 30 feet long and 12 feet high. The window extends the entire length and height of the room above a three-foot sill. In order to allow comparison with the experimental study, the following reflectance values were used: $\rho_{walls} = 0.7$, $\rho_{floor} = 0.3$, $\rho_{ceiling} = 0.8$, $\rho_{window\ (effective)} = 0.42$.

The unit configuration of the louvers is shown in Fig. 9. The louvers are the adjustable horizontal type used in conjunction with a flat glass window. As indicated, the geometry of the louver can be described by the slat width, W, the slat spacing, L, and the angle of tilt of the louver θ_L. W, L and θ_L for this study are 1.25, 1.00 and 45 degrees, respectively. A louver reflectance ρ_L of 0.70 is used. The analysis is restricted to a louver element rather than the entire system, for purposes of simplicity. This approach assumes that each element of the louver system behaves in the same manner, and what is characteristic of the element is also characteristic of the system. It is also postulated that the louver slat is infinitely long so that the problem can be reduced to a two dimensional representation. The basic shape modulus which describes the geometry of the space between the louver slats is, in terms of symbols of Fig. 9, as follows:

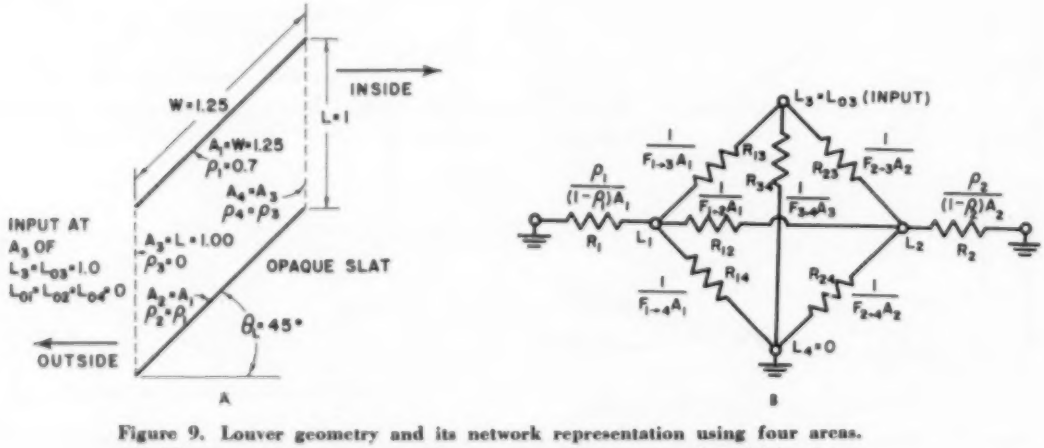

Figure 9. Louver geometry and its network representation using four areas. (A) Element of louver system with geometry, reflectances and initial luminous emittances as shown. (B) Network representation of louver using four areas.

$$F_{A_1 \to A_3} = \frac{1 + (L/W) - \sqrt{1 + (L/W)^2 + 2(L/W)\sin\theta_L}}{2} \quad (3)$$

The amount of flux coupled through the louver element is related to the sky, ground and direct solar inputs to the element by the expression:

$$E_4 = [L_{sky} K_S + L_{ground} K_G + L_{direct} K_D] \quad (4)$$

where:

E_4 = Total illumination including interreflections on surface A_4 in Fig. 9 (lumens per square foot).

K_S, K_G, K_D = Transfer functions for sky, ground and direct solar inputs as defined in following equations (dimensionless).

L_S, L_G = Average luminous emittances of the sky and ground, respectively (lumens per square foot).

L_D = Initial luminous emittance (before interreflections) of slat area exposed to direct solar illumination (lumens per square foot).

The contribution of the sky and ground to the illumination of A_4 (see Fig. 9) at the inside plane of the louver system is given by a part of Equation (4) as follows:

$$E_4\,(\text{sky} + \text{ground}) = (L_S K_S + L_G K_G) \quad (5)$$

If L_S is set equal to L_G in Equation (5) and the quantity E_4 is expanded in terms of the shape moduli and emittances of all surfaces which A_4 sees, the quantity $(K_S + K_G)$ is defined as:

$$(K_S + K_G) = \left(\frac{L_1 F_{4\to 1} + L_2 F_{4\to 2} + L_3 F_{4\to 3}}{L_G}\right) \quad (6)$$

As shown in Fig. 9, all flux entering the louver elements streams through A_3. If A_3 is assumed to have zero reflectance, the emittance of surface 3 is $L_G = L_S$. The louver element of Fig. 9A is represented by the network of Fig. 9B. The solution of this network will yield the values of L_1 and L_2 in Equation (6). Equation (6) allows the sum of the sky and ground transfer functions to be computed. For this particular problem the sky and ground emittances are the same, so that $(K_S + K_G)$ is the required transfer function.

A second quantity which can be obtained from the solution of the network representation of the louver element is the effective reflectance $\rho_{EFF.}$ of the louvers. The effective reflectance of the louver is the apparent reflectance of the louver cavity as seen from surface A_4 of Fig. 9A. The effective reflectance can be determined from the network by allowing surface A_4 to be the input surface. If $L_4 = L_{04} = 100$ volts $\rho_{EFF.}$ can be obtained by a relation similar to Equation (6).

$$\rho_{EFF.} = E_4 / L_4 = \frac{F_{4\to 1} L_1 + F_{4\to 2} L_2}{100} \quad (7)$$

L_1 and L_2 in Equation (7) are obtained from a solution of the network. L_3 does not appear in Equation (7) because A_3 is assumed to be black and acts as a luminous sink.

The quantities $(K_S + K_G)$ and $\rho_{EFF.}$ as determined from Equations (6) and (7) are shown in graphical form in Fig. 10 as a function of louver reflectance ρ_L. As indicated in Fig. 10, both $(K_S + K_G)$ and $\rho_{EFF.}$ vary directly as the louver reflectance. Numerical values desired from this portion of the study are $\rho_{EFF.}$ and $(K_S + K_G)$ at a louver reflectance of 0.7. These quantities are from Fig. 10: $(K_S + K_G) = 0.38$, $\rho_{EFF.} = 0.32$. The direct solar input to the louver occurs at the lower slat of the louver as shown in Fig. 11. The fraction of louver area which is illuminated by the direct input is dependent on the louver angle θ_L and the azimuth and elevation angles of the sun.

The contribution to E_4 of direct solar input to the louver is from Equation (4):

$$E_4\,(\text{direct}) = K_D L_D \quad (8)$$

The transfer function K_D for direct solar input was determined by using a ten-area division of the louver element shown in Fig. 11. Input voltages proportional to the direct solar input were applied successively to areas 5 through 8 representing the lower portion of the louver slat. K_D was computed

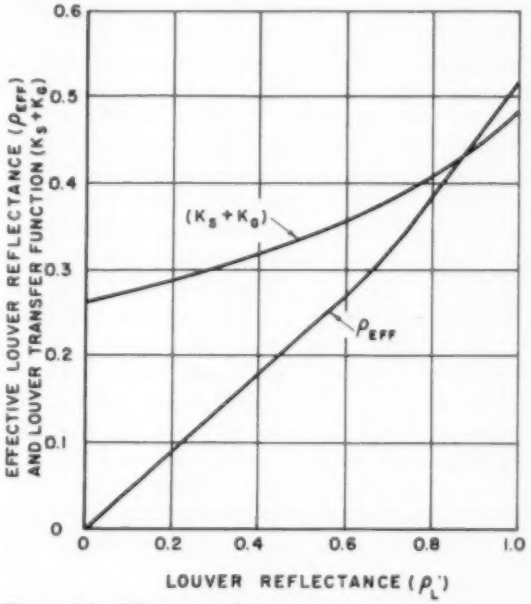

Figure 10. Effective reflectance and transfer function $(K_S + K_G)$ for sky and ground of louver element (Fig. 9A).

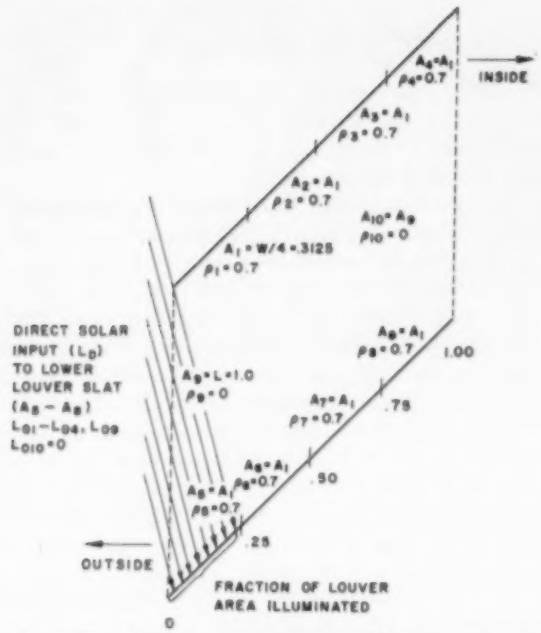
INSIDE
OUTSIDE
DIRECT SOLAR INPUT (L_D) TO LOWER LOUVER SLAT ($A_8 - A_8$) $L_{01} - L_{04}, L_{09} L_{010} = 0$
$A_1 = W/4 = .3125$ $\rho_1 = 0.7$
$A_2 = A_1$ $\rho_2 = 0.7$
$A_3 = A_1$ $\rho_3 = 0.7$
$A_4 = A_1$ $\rho_4 = 0.7$
$A_{10} = A_9$ $\rho_{10} = 0$
$A_9 = L = 1.0$ $\rho_9 = 0$
$A_8 = A_1$ $\rho_8 = 0.7$
$A_7 = A_1$ $\rho_7 = 0.7$
$A_6 = A_1$ $\rho_6 = 0.7$
$A_5 = A_1$ $\rho_5 = 0.7$
1.00
.75
.50
.25
0
FRACTION OF LOUVER AREA ILLUMINATED

Figure 11. Ten-area representation of louver element used for determination of direct solar transfer function, K_D (Equation 8).

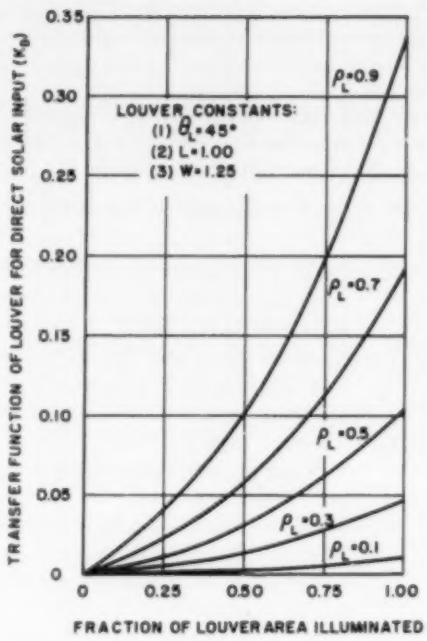

Figure 12. Direct solar transfer function of louver shown in Fig. 11.

for each case and plotted as a function of louver area illuminated. The resulting plot can be used to determine K_D for any fraction of the louver area illuminated.

The direct transfer function as determined from the solution of the network for the ten-element louver (Fig. 11) is shown graphically in Fig. 12. The direct transfer function K_D varies directly as louver reflectance and fraction of louver area illuminated. Note that K_D for constant values of illuminated area is highly dependent on louver reflectance. For example, an increase in reflectance of 0.2 (*i.e.*, from 0.5 to 0.7) at an illuminated area of 0.5 more than doubles the value of K_D. This points out the importance of louver reflectance in utilizing direct solar input. The magnitude of K_D for the louver and sun geometry of this problem is 0.027.

The analysis of the louver element yielded the transfer functions for the louver. The next step was the analysis of the room with the louvered window as the input. As shown in Fig. 8, the room was represented by ten areas so that an equivalent circuit could be constructed and solved on the Luminous Analogue Computer. The luminous emittances of all surfaces within the room were provided by the computer so that the illuminations at locations A through E at work plane level could be computed and plotted on Fig. 13.

The empirical and analytical values of illumination at points A through E are compared graphically in Fig. 13. In most instances, the analytical and experimental values of illumination compare very favorably. The exceptions are the analytical values of illumination at points B and C which deviate from the empirical values by about 15 per cent. This error in the analytical representation is

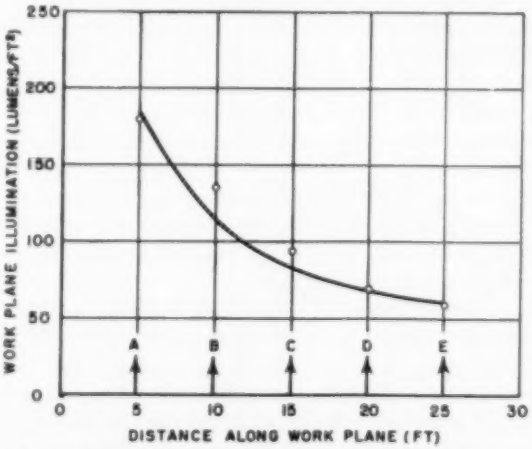

Figure 13. Illumination distribution along work plane of S. M. U. Test Room (Fig. 8). Solid line is plot of analytical values of illumination, data points are empirical values of illumination obtained from Table I (Test 2) of reference 9.

related to the postulate that the flux streaming through the louver system is perfectly diffuse. If the initial division of flux from the louvered fenestration to the room surfaces had been used, the analytical values of illumination at points B and C on the work plane would have been raised because the ceiling elements above these points receive an initial illumination higher than that computed for diffuse emission.

Conclusions

Some examples of the use of computers for the solution of the finite difference equations describing daylight transfer in rooms have been presented. In order to conserve space, many important but reasonably routine steps in the analyses have not been considered in detail. For example, the shape moduli were drawn from an extensive literature which cannot be reviewed here.

The comparison of room illuminations obtained by both experimental and analytical methods reveals that the finite difference equations can be an accurate tool for daylighting design. Before these techniques can become commonplace, however, the daylighting designer must adapt to the modern practices related to numerical analysis and computing machinery.

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DISCUSSION

R. G. HOPKINSON:* Analogue computers offer a means for rapid calculation of radiative transfer and should, in theory, be suitable for lighting calculations. Some years ago, at the Building Research Station in England, we built an electrical analogue for heat transfer problems, but when it came to lighting, it seemed as if the computer could only solve an infinity of simple problems — not the difficult ones that really bothered us.

An analogue computer which would include sufficient transfer surfaces for our needs would have to be very complicated and costly; and its programming would demand a great deal of time. Extensive series of tables of shape moduli are also necessary, or this computation would become a time consuming job in itself. So, at the time I refer to, the decision was made that those problems which could not be solved easily by our simplified interreflection formulae should be dealt with by means of models which are, after all, a form of analogue computer. We devised a system of quick erection of our models, and we can now set up a situation and measure it quickly enough for all practical needs.

Nevertheless, there is a real need for computers applied to both daylighting and electric lighting problems, and I applaud the efforts of the authors in tackling the job. At present, it will seem to daylighting specialists that the authors have had to invent easy problems for their computer to solve. The daylighting engineer is more often concerned with the adjustment of a complicated architectural fenestration to achieve a regulation daylight factor demanding a much wider variety of surface divisions, hence shape moduli, than the authors' present computer can deal with. However, the problem may be solved in the future with a more complicated analogue served by some means of automatic programming — the rapid running through of a predetermined series of window variants. The work, therefore, has a good future ahead of it, and I hope the authors will be encouraged to go ahead and develop their studies.

B. H. EVANS:* The use of a mathematical formula to predict luminous environment has merit and results in better understanding of the actions of light. The authors are correct in saying that empirical studies are not diverse or dynamic enough for a practical examination of all architectural conditions. They are also correct in saying that the analytical method is more flexible than the empirical method. However, the analytical method is not nearly as flexible or adaptable as the model testing method where daylighting is concerned.

Any mathematical system must depend on assumptions and standardizations resulting in approximate answers. The model testing method provides accurate results under any and all conditions regardless of the architectural design. Laboratory facilities and testing processes are not as expensive as the use of analytical computers.

In their conclusion, the authors say that the daylighting designer must adapt to numerical analysis and computing machinery, but I feel that a more desirable condition is for the prediction system to adapt to the designer.

A. DRESLER:** I have studied the paper by Messrs. O'Brien and Howard with considerable interest. I would like to offer my congratulations to them for having shown so convincingly that the computer is in a position to predict accurately a complex situation of daylighting design which cannot be handled economically in any other way.

It seems to me, however, that this is only a first step. One cannot expect the engineer or architect to submit individual design problems to the complicated computer procedure each time they occur. What is needed is someone who is willing to put the computer to work on a sufficiently wide variety of what may be called "normal" conditions of

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*Coordinator of Architectural Research, Texas Engineering Experiment Station, Texas A & M College, College Station, Texas.
**Department of Labour and National Service, Melbourne, Australia.

daylighting design with the aim of providing some sort of pre-digested information from which the designer can pick the solution to the case he has in mind.

In compiling these pre-digested data, particular emphasis would have to be placed on selecting realistic conditions, not only with regard to the type of fenestration, the size and shape of rooms and their interior decoration, but particularly to outside conditions. I fail to see the advantage of applying an expensive piece of equipment to conditions which in reality do not exist, such as the sky of uniform luminance or the diffusing vertical window with a constant luminance distribution throughout. I would also like to suggest that one should not try to achieve too much at a time. Must we really know the daylighting conditions of an interior under all sorts of external conditions — for sunshine, white clouds, blue sky, snow-covered ground, etc.? We know perfectly well that when the sun shines the level of daylighting will be much higher than when the sky is overcast. What we do not know, and require an answer to, is the question: "For how many working hours per year will the daylighting in the worst lit parts of a room be adequate (or better) to perform a certain visual task?" Posing the problem in this way means that in daylighting design we want to find out what constitutes reasonable minimum conditions for which to choose the type and size of the fenestration. This automatically leads to the selection of a standard sky of reference luminance and luminance distribution which, in turn, depend on geographical latitude, meteorological records of hours of sunshine and on the number of normal working hours during which daylighting may be below the design level.

BILL F. JONES:* This paper gives another example of the tremendous applicability and flexibility of the finite difference equations, when combined with computers, for solving lighting problems. I feel that, when the unfamiliarity with the system is dissipated, a large number of the problems which we have been unable to solve will become quite easy.

The major problem at the moment seems to be the availability of the shape factor, or shape modulus. This quantity has been in use in the heat transfer field for some years, and an excellent compilation can be found in NACA Technote 2836, where it is called the Radiant Interchange Configuration Factor. This Technote is available from the Department of Printing in Washington. Moon in his *Scientific Basis of Illuminating Engineering* also has a table of flux transfer equations which can readily be converted to shape factors.

Table II shows that the errors in the analogue solution as compared with an exact solution run on the order of between one and two per cent. Our experience with a computer of this type indicates that with care in making the resistance and input settings, the error is closer to one-half per cent. I feel that probably the major source of the authors' error is in their metering equipment. By using a potentiometer with 0.1 per cent linearity, we feel we reduce our metering error to approximately this magnitude, and in fact have been able to solve mathematically soluble problems to accuracies in the neighborhood of two to three tenths of a per cent.

The number of potentiometers to be set on a computer of this type is roughly proportional to the square of the number of surfaces the computer will handle. From working with a twelve-surface computer, I feel that, while a computer of fifteen or twenty surfaces could be readily constructed, it could not be justified for research or design work. Not only do the time involved and the chances of error in making a setting increase greatly, but also there are methods available for reducing the number of surfaces required. Among these are symmetry considerations, treating of parts of an enclosure as cavities with an effective reflectance, and experience in discretization of enclosure surfaces. Some investigation of these last two should be made to formulate them into procedures.

JEAN DOURGNON:* I was very interested in the paper by Messrs. O'Brien and Howard and, I must say, by all the new daylighting studies that are being made in the United States. Since there are relatively few workers throughout the world in the daylighting field, international cooperation is especially useful.

It seems bold to assume that the flux leaving the louvers is perfectly diffused and I am surprised that the error is less than 15 per cent in the worst case. Nevertheless, I think that if the comparison had been made for the luminances of the ceiling or of the floor the error would have been greater.

The authors' equation deals with flux over large areas of the boundary surfaces, or, if you prefer, mean emittance over those very areas. How do the authors obtain curves of actual illumination on the working plane which is not a boundary surface?

The room of Figs. 3 and 8 involves ten areas for the computation. As we have the walls normal to the window, that makes 12. Is this correct?

PHILIP F. O'BRIEN AND JAMES A. HOWARD:** The authors wish to thank the discussers for their helpful and stimulating comments.

Dr. Hopkinson is correct in stating that a physical model is a form of analogue computer but the electrical analogue model or computer is characterized by elements (*i.e.*, electrical resistances) that are easily adjusted over a continuous range of surface reflectance, geometry and directional properties of the fenestrations. For example, it is difficult to conceive of a physical model whose surface reflectance could change as easily as a variable resistance can be changed by a twist of a knob like the volume control on a radio.

Dr. Hopkinson points out that two deficiencies of an analogue computer for handling difficult lighting problems are: (1) Prohibitive cost of constructing a computer with a sufficient number of transfer surfaces for handling involved problems; (2) Time demand in programming the computer because of the extensive job of obtaining the necessary shape moduli. Dr. Hopkinson is partially, but not wholly correct. It is possible to handle involved lighting problems with a computer having a small number of surfaces (*e.g.*, ten) by proper selection of the size and number of lumps or discretized areas. Some general rules or guides which are helpful in reducing the number of areas for a specific problem are as follows:

(1) Natural breaks in the geometry such as boundaries between regions of different reflectance should be employed.

(2) Symmetrical conditions which allow the space to be halved or quartered should be observed.

(3) If one region of a space, such as the volume between the plane of the luminaires and the work plane, is to be considered in detail, other parts of the space can be lumped by the technique of effective reflectance.

(4) Certain three dimensional spaces can be reduced to

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**Authors.

two dimensional representations by the postulate that one dimension is infinite in extent. In general, this postulate does not produce unreasonably large errors. By using the foregoing guides a lighting problem which may appear to be very complex can often be simplified to such an extent that it can be solved on an analogue computer having only a small number of transfer surfaces. For instance, the louver daylighting problem described in the paper was solved on a ten-surface computer by employing several of the guides listed above.

Another feature of the network representation of luminous transfer systems is that the tools of network analysis and synthesis may be used on lighting problems. In many instances the size of a network representing a luminous transfer system may be reduced by proper application of appropriate network theorems. For example, O'Brien has recently employed the technique of mesh to tree transformation for simplification of the network of a lighting problem.

The statement by Mr. Evans that laboratory facilities and testing processes for model studies of daylighting are not as expensive as the use of analytical methods is contestable. The use of analytical as well as experimental methods is common in modern design practice characteristic of most technical areas. It is clear that the professional engineer with paper, pencil and computing facilities can make major progress in design before model or prototype testing is required.

Dr. Dresler is correct in stating that computers could be employed to generate large quantities of data in tabular form applicable to daylighting design. However, this approach could not possibly cover all daylighting situations. A more realistic approach would be for the daylighting designer to learn to use computers as tools in his design work. Computer procedure is not so complicated that the engineer or architect could not adapt to its use after a little study.

As suggested by Mr. Jones, the shape modulus is a geometrical parameter fundamental to the analytical representation of daylighting problems. Although this quantity is represented by an extensive literature it is not common knowledge among lighting designers. A concentrated effort to bring this knowledge of radiant geometry to lighting designers is required before analytical methods will become part of general design practice.

In response to Dr. Dourgnon, the work plane illumination is obtained from the relation

$$E_A = \sum_{n=1}^{n=m} L_n F_{dA_A \rightarrow A_n} \qquad (1)$$

where

E_A = Illumination of point A on the work plane in Fig. 8;

$L_1, L_2, \ldots L_n$ = Average total luminous emittances after all interreflections of all surfaces within the enclosure which point A sees.

$F_{dA_A \rightarrow A_n}$ = Differential area to finite area shape modulus, the fraction of diffuse flux streaming from dA_A which is directly intercepted by A_n.

The differential area to finite area shape modulus $F_{dA_A \rightarrow A_n}$ is not to be confused with the finite area to finite area shape modulus $F_{A_A \rightarrow A_n}$. These shape moduli are related as follows:

$$F_{A_A \rightarrow A_n} = \frac{1}{A_A} \int_{A_A} F_{dA_A \rightarrow A_n} dA_A \qquad (2)$$

Because the differential area to finite area shape modulus $F_{dA_A \rightarrow A_n}$ is more easily obtained by direct integration or by various experimental methods, the finite area to finite area shape modulus $F_{A_A \rightarrow A_n}$ is often obtained by the approximate numerical solution of Equation 2.

In actual practice the illumination at a number of points on the work plane such as A through E in Fig. 8 is obtained by successive applications of Equation 1. This allows one to plot the illumination distribution along the work plane as has been done in Fig. 13 of the paper.

The room depicted in Fig. 3 of the paper involves only ten areas for the computation. For this particular problem the room was postulated to be infinitely long with respect to the width. As a result the problem is reduced to a two dimensional problem which neglects end wall effects. Postulating that an enclosure is infinitely long with respect to the width when it actually is only twice as long does introduce an error. However, the error is relatively small as long as the room is at least twice as long as it is wide.

The enclosure shown in Fig. 5 involves only ten areas for computation. However, for this problem end wall effects were not neglected. Thus in Fig. 3 the cross section is represented by areas 1 through 8 and the end walls (not shown) by areas 9 and 10, respectively.

It should be pointed out that the application of network analysis to lighting problems is a recent development and much more work needs to be done in this area. Eventually the lighting designer should be able to handle even the most complex lighting problems with ease by employing formal methods of network analysis and synthesis.

Exercise your privilege to vote . . .

in the election of National and Local IES Officers. Your ballots will be reaching you early in April and, to be counted, must be returned to the General Secretary, at headquarters, by May 26.

Here and There With I.E.S. Members

Future IES'ers being recruited in St. John, N. B. at the Maritime Chapter's Christmas "kiddie" party.

Ladies' Night meeting of the St. Louis Section featured local optometrist, Dr. Bernard C. Jander speaking on "Light and Vision." Shown here at the speakers' table are, from left to right, Mrs. Edwin H. Lauth, Edwin H. Lauth, Mrs. Charles Zurheide, Section Chairman Charles Zurheide, Dr. Jander, Program Chairman Norman Krause, Residence Lighting Forum Chairman Dorothy Davis and Vice-Chairman Willis Mangold.

Seen at the January meeting of the Eastern Pennsylvania Section of IES, held at the Hotel Abraham Lincoln in Reading, Pa. are, seated, from left to right in photo at left: Frank Heins, Program Chairman; C. C. Shotwell, East Central Regional Vice-President; R. J. Pretzman, Section Chairman and R. A. Reynolds, Secretary-Treasurer. Standing are R. C. Hamsher and J. H. Bicher, Board of Managers. In photo at right, guest speaker, E. A. Linsday, Chairman of the Progress Committee of IES, is flanked by Section members J. F. Beiter (left) and W. V. Wivel. Program: Mr. Linsday's presentation of the 1958 Progress Report, "Reaching for the Sun."

LIGHTING NEWS

Central Florida Chapter Approved as No. 85

The number of local groups in IES has increased to 85, as the Council of the Society approved the petition of the Central Florida Chapter at its February 12 meeting. Petition was submitted by J. Dixon Mitchell, former V-P of the Southeastern Region and now a Director.

The Chapter will include seven counties in the central portion of the state and Daytona Beach. Headquarters is in Orlando.

Clinic for Industrial Lighting

New York Section was sponsor for a valuable symposium on lighting in industry held January 15 at Tavern on the Green. Five sessions were featured, each covering a pertinent phase of industrial lighting. Some 150 attended.

Beginning at noon, the clinic continued through a dinner at the Tavern. Guest speaker at dinner was Gerald Quinn, electrical editor for *Factory Management and Maintenance* magazine. His very provocative (and informative) subject was "How Does Industry Accept Higher Lighting Levels?"

Program for the Clinic consisted of:

(1) Quality and Quantity of Lighting in Industry — C. L. Crouch, Illuminating Engineering Society.
(2) Fluorescent Lamps and Applications — Robert Zahour, Westinghouse Electric Corp.
(3) Mercury Lamps and Filament Lamps and Applications — Russ Churchill, General Electric Co.
(4) Electrical Distribution for Lighting — Mark Eitingon, Eitingon & Schlossberg Associates.
(5) Maintenance of Lighting Systems—George J. Taylor, Day-Brite Lighting Inc.

Items from the February Council Agenda

At its February 12 meeting, the IES Council received various reports and made several actions not reported upon elsewhere. These include:

Alaska and Hawaii Assigned to IES Regions. On the recommendation of the Regional Activities Committee, the State of Alaska and the Territory of Hawaii were attached to the Pacific Northwest Region and the South Pacific Coast Region, respectively. Newfoundland had previously been attached to the Canadian Region.

Membership Up 4½% since October! The Board of Examiners reported an increase of 406 members since the beginning of the fiscal year, bringing the total membership to 9389.

Pin Designed for Past-Chairmen. A Task Committee, headed by C. C. Shotwell, has developed a special pin for Past-Chairmen of Sections and Chapters. It is available in red, blue or white, designating the present grade of the Past-Chairman as Associate Member, Member, or Fellow. Sections and Chapters wishing to honor their past officers may purchase these from Headquarters (John Michel, Membership Secretary) at a cost of about three to three and one-half dollars. Such requests should specify current grade of membership of the Past-Chairman.

MMILJ National Entries Can Use Proxies and/or Tape Recordings. If a first prize winner in the contest for MMILJ at the Regional level cannot attend the National Technical Conference to present his entry, he can now use a proxy from outside his Region or a tape recording describing his entry, with slides which will also be presented.

Plans Made for Post-Conference Hawaiian Trip

American Express Co. is handling arrangements for trips to Hawaii for IES'ers following the Conference in San Francisco this September. Airplane, hotel and steamer reservations in the following order are being held:

35 first class seats and 25 tourist class seats on United Airlines, San Francisco to Honolulu, morning of September 12.
32 first class seats and 20 tourist class seats on Pan American, leaving San Francisco the evening of September 11. This is an entire plane and, if necessary, the classes can be juggled to seat more or less of either class.

(*Continued on page* 10A)

INDUSTRIAL Lighting Clinic sponsored by New York Section, January 15, featured these speakers: l. to r. Mark Eitingon, Consulting Engineer; R. L. Zahour, Westinghouse; Jack Hamilton (Section Chairman); G. J. Taylor, Day-Brite (IES President); R. D. Churchill, General Electric; C. L. Crouch, IES Technical Director; Gerald Quinn, *Factory Management and Maintenance*.

(*Continued from page* 9A)

20 first class and 15 tourist seats Honolulu to San Francisco on Pan American leaving the evening of September 19.

15 first class and 10 tourist on the Pan American plane leaving the evening of September 26.

Accommodations for those members who prefer to return by steamer, either on the *S.S. Matsonia* September 21 arriving Los Angeles September 26, or the *S.S. Lurline*, September 26, arriving San Francisco on October 1.

Accommodations for 100 persons at the Royal Hawaiian Hotel in Honolulu, September 12 to 19, with specially planned entertainment.

Arrangements for 40 persons to take several extension tours around the Islands.

These arrangements and reservations are as reported by the American Express Co., 253 Post Street, San Francisco, Calif., to J. S. Walsh, Chairman of the 1959 Conference Executive Committee.

Nominations Submitted for Election of National Officers

Nominations for 1959-1960 election of national officers were reported to Council February 12 by the Board of Nominations, R. F. Hartenstein, Chairman. The slate to be offered for member ballot will be:

President: J. B. Browder, Jr.
Second Vice-President: J. R. Chambers
General Secretary: C. W. McCormick
Treasurer: Frank Dean
Directors: J. S. Hamel and
W. P. Lowell, Jr.

R. G. Slauer, elected to a two-year term last year, will continue as First Vice-President.

Officers Chosen By ASHRAE

Cecil Boling of West Hartford, Conn. has been elected the first president of the American Society of Heating, Refrigerating and Air Conditioning Engineers, an organization created by the merger of the American Society of Heating and Air Conditioning Engineers and the American Society of Refrigerating Engineers in January of this year. Other officers elected to serve the society in its first year are: A. J. Hess, Los Angeles, Calif., First Vice-President; D. D. Wile, Los Angeles, Calif., Second Vice-President; W. A. Grant, Syracuse, N. Y., Third Vice-President; R. H. Tull, Springfield, Mass., Fourth Vice-President; John Everetts, Jr., Philadelphia, Pa., Fifth Vice-President; J. H. Fox, Toronto, Ont., First Treasurer and F. Y. Carter, Detroit, Mich., Second Treasurer.

Total membership in the consolidated Society is more than 18,000.

Catalog of Educational Materials Offered by BLBS Bureau

A comprehensive catalog of educational materials on the benefits of good lighting, said to be the largest ever assembled, has been offered to the electrical industry by the Better Light Better Sight Bureau. Materials available include several new items published at the end of 1958, and cover lighting education activities at the consumer and school levels. Each item is designed to increase public understanding of the need for better lighting, thus aiding lighting promotional plans of utilities, electrical leagues and equipment manufacturers.

Booklets available include *Eyes, Our Windows to the World, How to Make Homework Lighter, Sherlock Ohms and Dr. Watts* and *Light, an Aid to Sight.* Also available are BLBS plastic bookcovers and "Light Is What You Make It," a 10-minute color film produced for the Bureau by Walt Disney.

The Better Light Better Sight Bureau, sponsored by the electrical industry, was organized in June 1934, and celebrates its Silver Anniversary this year.

Fundamentals Course Conducted by Ottawa Section

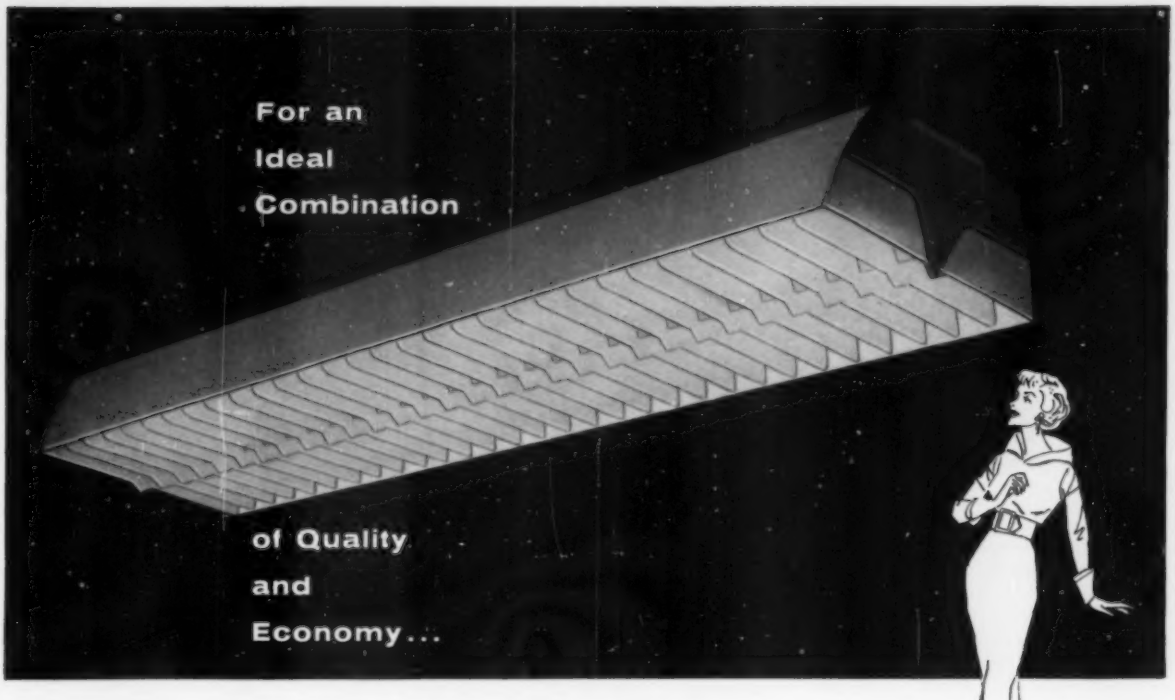
Under the chairmanship of W. G. Montabone, the Ottawa Section of IES recently conducted an eight-session course in the fundamentals of illumination. The course, held from January 21-March 11, had an enrollment of 50. Classes were given in the Electrical Engineering Building of the University of Ottawa. The first half of the course was devoted to the fundamentals of light and sight; the second part covered applications, both interior and exterior.

Program and lecturers were:

January 21 — Lighting and Sight, Rev. Fr. D. E. Cahill, St. Patrick's College, Ottawa, Ont.

(*Continued on page* 12A)

HIGH-POWERED research meeting of the Southern California Section Study Club featured on the program, from left to right, Dr. H. Richard Blackwell; IES Technical Director C. L. Crouch; Cornell University Professor E. M. Strong, Chairman of the Research Executive Committee of IERI and John Chorlton, Chairman of the Society's School Lighting Committee. Topic, of course — the Blackwell researches and their ramifications. In addition, Professor Strong discussed the other work being carried on by the Research Institute. Following this highly-technical Study Club meeting, 150 members at the Section meeting were treated to the same speakers.



go modern with Sylvania's new Fixture Series...

THE TARTAN

If you have an interest in quality lighting fixtures that feature attractive appearance, efficiency, and versatility, you'll want to know more about Sylvania's new Tartan Series.

This fresh new fixture series offers appealing design and shallower depth for neat, streamlined appearance . . . a wide selection of matching units in 2-lamp and 4-lamp widths in both 4′ and 8′ lengths . . . and the availability of either metal or plastic side panels in any unit. With the Tartan Series you also have a choice of metal louvers with two different cut-offs to tailor the fixtures to the application.

All of these features plus the moderate cost of this up-to-date fixture series now put attractive quality lighting within the reach of everyone planning a lighting installation, whether large or small.

The versatility and high efficiency of the Tartan Series make it the ideal means of lighting for many schools, offices, stores, and other commercial applications as well as for industrial uses where quality lighting is desired.

See for yourself how the Tartan Series can fit your lighting plans. Write for complete information today to:

SYLVANIA LIGHTING PRODUCTS
A Division of SYLVANIA ELECTRIC PRODUCTS INC.
Department 59-3
One 48th Street, Wheeling, West Virginia

Have you kept up to date with the broad range of fluorescent lighting systems and fixtures offered by Sylvania? If not, send for a complete fixture catalog today. A brief glance at the large variety of types and styles of Sylvania lighting equipment will show you why we say—"Go Modern with Lighting by Sylvania."

GO MODERN WITH LIGHTING BY **SYLVANIA**

Fluorescent Lighting Fixtures and Systems

BEST FIXTURE VALUE IN EVERY PRICE RANGE

LIGHTING • TELEVISION • RADIO • ELECTRONICS • PHOTOGRAPHY • ATOMIC ENERGY • CHEMISTRY-METALLURGY

C. L. CROUCH, at right in photo at left, discussed the new Recommended Levels at the January meeting of the Philadelphia Section. Shown here with Mr. Crouch are, l. to r., Arthur B. White, Philadelphia Chapter of the American Institute of Architects; Warren F. Bower, President of the Greater Philadelphia Plant Engineers Club and C. C. Shotwell, Regional V-P. At right are some of the 225 who were in attendance at the meeting.

(*Continued from page* 10A)

January 28 — Lighting Fundamentals, A. D. Miller, Consulting Engineer, Ottawa, Ont.
February 4 — Light Sources, M. J. Cote, Canadian Westinghouse Co., Ottawa, Ont.
February 11 — Illumination Design, G. D. Mills, Department of National Defence, Directorate of Works, Ottawa, Ont.
February 18 — Industrial, Office and School Design, M. Strang, Curtis Lighting Co., Toronto, Ont.
February 25 — Store Lighting, D. Hazelgrove, Charles Ogilvy, Ottawa, Ont.
March 4 — Exterior Lighting, D. R. Thornton, Canadian Line Materials Ltd., Ottawa, Ont.
March 11 — Residential Lighting — F. G. Reed, Architect, Toronto, Ont.

Computer Service Available For Zonal Method Calculations

With digital computers playing an increasingly large part in the lighting field, an electro-optical computing service for calculating coefficients of utilization by the Zonal Method was, some time ago, instituted — in part through the efforts of the Lighting Design Practice Committee.

This service can be purchased on a per-table basis for various reflectance combinations for ceilings, walls and floors. Further information is obtainable from Electro-Optical Computing Service, 1017 El Centro St., South Pasadena, Calif.

French and German Standards Available in Translation

English translations of French and German industrial standards are now being made available in this country through the American Standards Association. Thirty translations have been received from the Association Francaise de Normalisation, the French standards body, covering, among other things, zinc alloy ingots, blast furnace cements and conveyor belting. From Deutscher Normenausschuss, the German standardization organization, 175 translations have already been received, and 57 more are expected shortly. Subjects covered in these standards include screws, washers, nuts, bolts and test methods for steel and various nonferrous metals.

ASA has on file and available for sale a large selection of foreign engineering and industrial standards, most of them, however, in the language of their country of origin. France and Germany are two of the few nations that have begun systematic translations of their standards as a means of promoting export sales.

A complete list of the available foreign standards can be ordered from ASA, 70 East 45th St., New York 17, N. Y.

Chicago Institute Schedules Office Lighting Program

On Thursday, March 19, 1959, a full-day clinic on contemporary office lighting will be underway at the Chicago Lighting Institute. The clinic is being sponsored by the Institute, the Chicago Section of IES and the Building Managers Association of Chicago. Building managers, office managers, architects, decorators, office equipment manufacturers and lighting engineers are among those who are expected to be attracted by the program which includes:

Morning Session

Chairman — A. J. Escher, Vice-President, Office Management Association and Office Manager, American Institute of Baking.
Lighting in Action — Carl W. Zersen, Chicago Lighting Institute, Chicago, Ill.
Seeing Research and Employee Efficiency — Eric H. Church, Lighting Products Inc., Highland Park, Ill.

(*Continued on page* 17A)

I.E.S. National Technical Conferences

1959 — September 7-11 — Hotels Fairmont and Mark Hopkins, San Francisco, California

1960 — September 11-16 — Penn Sheraton Hotel, Pittsburgh, Pennsylvania

1961 — September 24-29 — Chase Park Plaza Hotel, St. Louis, Missouri

1962 — September 9-14 — Statler-Hilton Hotel, Dallas, Texas

1963 — — Sheraton-Cadillac Hotel, Detroit, Michigan

NOW YOU CAN HAVE BOTH

FAMOUS ALL-BRITE HI-OUTPUT INDUSTRIAL

PLUS

A NEW 30° MATCHING LOUVER for GUIDED LIGHTING . . .

ALL-BRITE
ALL NEW
LOUVER Power Groove

DESIGNED SPECIFICALLY FOR ALL THESE GREAT LAMPS:
VHO, SHO, Power Groove

BUILT LIKE A HEAVY-DUTY TRUCK:
STRONG, SOLID, SAFE

send for catalog and data sheet

All-Brite
LIGHT OF AMERICAN COMMERCE

ALL-BRITE FLUORESCENT FIXTURES, INC.
352 SHAW ROAD, SOUTH SAN FRANCISCO, CALIF.

PLANTS ALSO IN LOS ANGELES AND SEATTLE.
IN CANADA: ALL-BRITE LIGHTING (B.C.), VANCOUVER, B.C.
REPRESENTATIVES THRUOUT THE UNITED STATES AND CANADA

Leading Industries and Architects Use American Lighting Louvers

Because American Plastic Louvers illuminate hallways, cafeterias and conference rooms, they are employed to give soft and glare free, efficient, inexpensive visual comfort. They are maintenance free. So for the ultimate in modern lighting design, specify American Plastic Louvers.

FOR CONTRACTORS AND ENGINEERS

There is a total absence of welding, riveting, and surface brightness with American Plastic Louvers. Their open construction permits freedom of air flow, helps diffuse heat or air conditioning, and allows free sprinkler operation.

Our engineers in your area are available to help with your lighting problems. For additional information, write for a detailed bulletin.

The dining area is lighted by troffers on a beam centerline flanked by 4 ft. wide continuous strips of plastic louvered ceiling. Deluxe warm white tubes on 8 inch centers are operated at 200 milliamps.

CREDITS

- Architects: *Wilton Becket and Associates, Los Angeles*
  Albert Kahn and Associates, Detroit
- Electrical Installation: *Triangle Electric Co., Detroit*
- Lighting Fixtures: *Fullerton*

SPECIFY AMERICAN PLASTIC LOUVERS . . .
AND BE SURE OF THE BEST IN
MODERN LIGHTING DESIGN

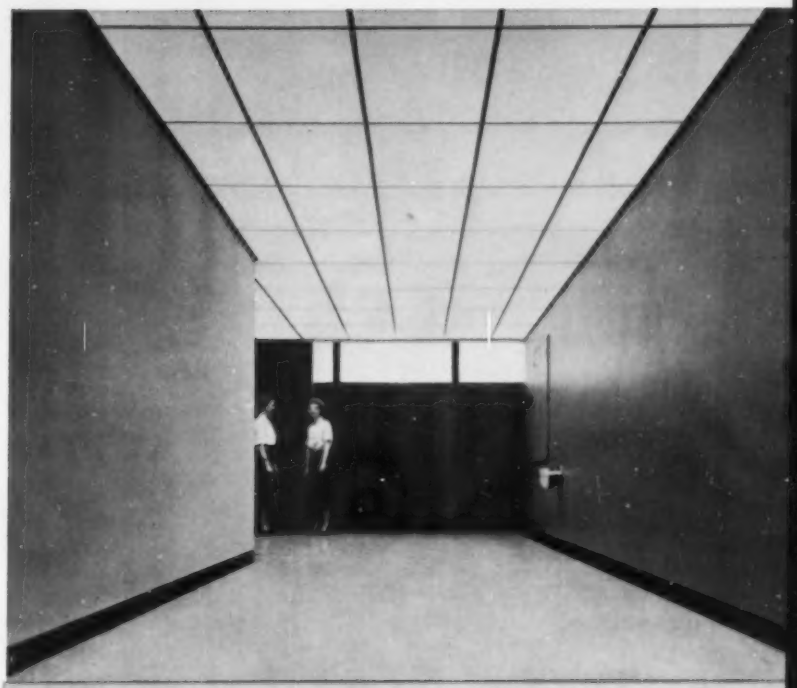
american louver company

4240 NORTH SAYRE AVENUE • CHICAGO 34, ILLINOIS

USA Pat. No. 2,566,817
USA Pat. No. 2,607,455

Canadian Pat. No. 484,346
Canadian Pat. No. 497,047

Why Lustrex* Perma Tone Styrene for ceilings?



Louvers made by American Louver Company of Lustrex perma tone. Installation by Triangle Electric. In Ford lobby luminous ceiling with 45° shielding lights 1100 sq. ft. Height to louvers: 12′; lamp spacing: 18″; ceiling brightness: 111 F.L.; walls: 10 F.L.; floor: 24 F.L.

In 90 x 120 ft. cafeteria, louvered strips, 4 ft. wide, run horizontally under ventilating ducts. Depth of cavity: 6½″. Ceiling brightness: 220 F.L.; tables: 85 F.L.; floor: 29 F.L.

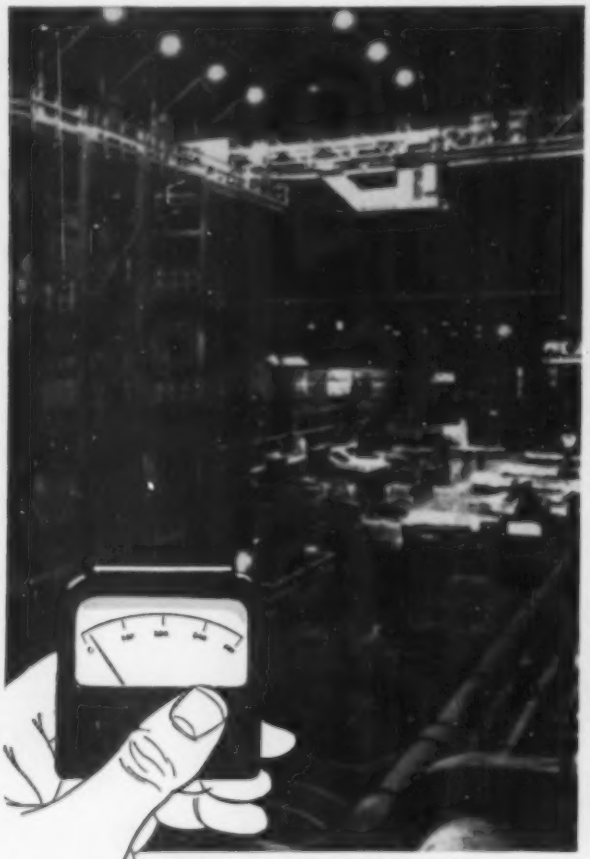
3 TIMES MORE COLOR STABILITY THAT'S WHY!

One of the striking features in Detroit's new Ford Division General Office Building, designed by the famous architectural firms of Wilton Becket & Associates of Los Angeles and Albert Kahn & Associates of Detroit, is the use of luminous ceilings. Halls, cafeterias, and conference rooms are softly, beautifully lighted by the glare-free illumination provided by Lustrex perma tone white styrene louvers.

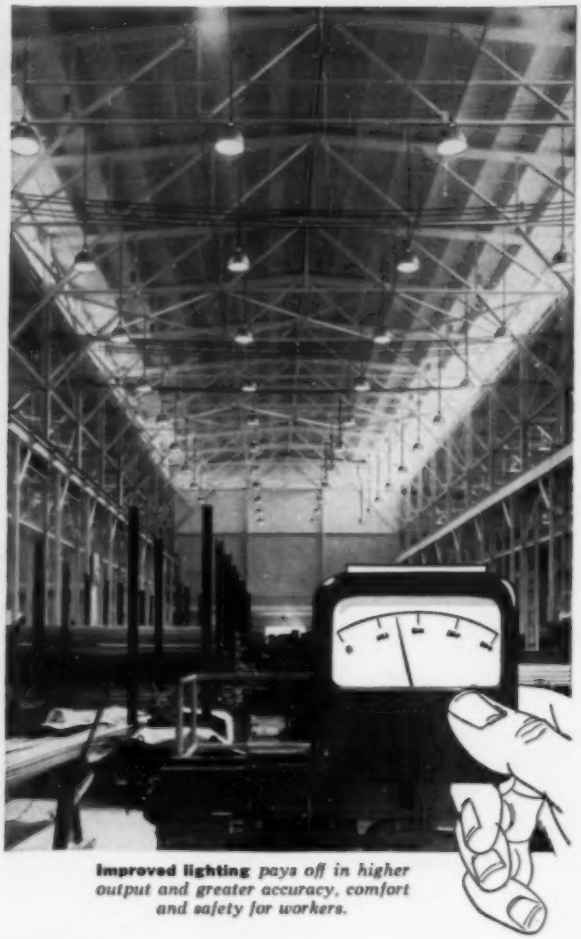
To all the obvious advantages of styrene in lighting (large areas of illumination, light weight, good diffusion, unusual design effects), Lustrex perma tone adds excellent ultra violet stability. Specially developed to meet IES–NEMA–SPI joint specifications, Lustrex perma tone offers truly translucent whites and a wide range of colors. Write for free technical report on perma tone, including accelerated test results and other valuable data on styrene in lighting fixtures to Monsanto Chemical Company, Plastics Division, Room 1316, Springfield 2, Mass.

Monsanto

*LUSTREX: Reg. U.S. Pat.



Dull, dreary lighting *cuts down worker efficiency, causes eye strain, makes many work tasks hazardous.*



Improved lighting *pays off in higher output and greater accuracy, comfort and safety for workers.*

Lifting the lighting level

In the picture on the right, those Abolite fixtures provide a high level of comfortable, glareless light throughout this high bay building. 18% of the light is directed upward through Abolite's open top, washes out the deep shadows, gives lamps a soft background. 35° shielding of lamp practically eliminates glare.

Open-top design also gives Abolite high bay units a self-cleaning action. Air circulates through the fixture, sweeps reflecting surface clean.

Choose from several Abolite uplight units for high bay lighting: 18" and 24" Alzak aluminum fixtures for 400 and 1000 watt mercury lamps; and 14" and 18" fixtures for 300-500 watt incandescent lamps (ideal for gymnasium lighting). For full information, write *Abolite Lighting Division, The Jones Metal Products Company, West Lafayette, Ohio.*

Abolite Cat. No. HMFAU-2400 Alzak aluminum uplight fixtures with 400 watt white reflector Mercury lamps.

ABOLITE *Lighting*

THE JONES METAL PRODUCTS COMPANY

West Lafayette, Ohio

(*Continued from page* 12A)

Light Sources for Offices — Raymond E. Wozniak, Chicago Lighting Institute, Chicago, Ill.
Lighting Systems for Offices — Carl Basedow and David Mason, Mason and Basedow Co.

Afternoon Session

Chairman — James R. Sterling, Secretary, Building Managers Association of Chicago.
Integration of Lighting, Heating and Air Conditioning — A. J. Morelli, Commonwealth Edison Co.
Lighting Dollars Make Sense — Richard M. Smart, Sylvania Electric Products Inc.
Exploring the Institute Quarters — Institute Staff.
Lighting Horizons Unlimited — B. F. Avery, General Electric Co.

The registration fee of $10 for the full-day program also includes a luncheon.

Advanced Illumination Course Offered by New York Section

A ten-week advanced illumination course in Lighting Design and Layout is one phase of the New York Section's program for Spring 1959. The course, which began on March 9, is being conducted at the offices of the Holophane Co. in New York City. Curriculum covers the design of installations for commercial and industrial areas as well as the latest trends in illumination. Plans call for the adoption of the Third Edition of the *IES Lighting Handbook* as the text for the course, upon publication of that book.

Fifteen dollars covers the cost of the ten-session course for members of IES, AIA and AIEE; fee for all others is $20.

Program and faculty are:

March 9 — Interior Lighting Design — L. Goren, Globe Lighting Products, Inc.
March 16 — Advanced Lighting Calculations — L. Goren.
March 23 — Industrial Lighting, Part I — N. Falk, Holophane Co., Inc.
March 30 — Industrial Lighting, Part II — N. Falk.
April 6 — Office Lighting, Part I — R. Wissoker, Day-Brite Lighting, Inc.
April 13 — Office Lighting, Part II — R. Wissoker.
April 20 — Public Building Lighting — H. Wald, Wald & Zigas.
April 27 — Store Lighting — H. Wald.
May 4 — Outdoor Lighting — R. Crockett, General Electric Co., Inc.
May 11 — General Review — R. Crockett.

Materials Sciences Division Organized by ASTM

To coordinate and intensify the development of the knowledge of the fundamentals of materials, a new Division on Materials Sciences is being organized by the American Society for Testing Materials. This Division will be concerned with the collection, establishment and publication of the basic information essential to a better understanding of materials and their properties. Specialists from various fields will be brought together under this plan to engage in basic research and to coordinate research activities relating to fundamentals now underway in many of the Society's technical committees.

Development of the new Division is under the direction of four ASTM officers, President K. B. Woods, School of Engineering, Purdue University; Vice-President F. L. LaQue, The International Nickel Co., Inc.; Vice-President A. Allan Bates, Portland Cement Association and Society Executive Secretary Robert J. Painter.

The new Division is one of several developments recommended by the Society's Long-Range Planning Committee. Other programs recommended by the Committee and now in operation include the Administrative Committee on Education in Materials and the awarding of fellowships and grants-in-aid for the study of materials.

SCHEDULED EVENTS

March 24-26, 1959 — Fifth Biennial Chicago Electrical Industry Show, Hotel Sherman, Chicago, Ill.

April 1, 1959 — Inter-Society Color Council (28th Annual Meeting), Statler-Hilton Hotel, New York, N. Y.

April 9-10, 1959—East Central Regional Conference, Lord Baltimore Hotel, Baltimore, Md.

April 22, 1959—Council Executive Committee Meeting, Illuminating Engineering Society, Grove Park Inn, Asheville, N. C.

April 23-24, 1959—South Central and Southeastern Regional Conference, Grove Park Inn, Asheville, N. C.

April 27-29, 1959 — National Association of Lighting Maintenance Contractors, Annual Convention, Cosmopolitan Hotel, Denver, Colo.

May 3-8, 1959 — Society of Motion Picture and Television Engineers, The Fontainbleau, Miami Beach, Fla.

May 4-5, 1959 — Southwestern Regional Conference, Shamrock-Hilton Hotel, Houston, Tex.

May 6-8, 1959 — Midwestern Regional Conference, Pere Marquette Hotel, Peoria, Ill.

May 6-8, 1959 — Electrical Manufacturers Representatives Association of Michigan (1959 Electrical Exhibit), Detroit Artillery Armory, Detroit, Mich.

May 11-12, 1959 — Inter-Mountain Regional Conference, Continental Hotel, Denver, Colo.

May 20-21, 1959 — Building Research Institute Conference on Building Illumination, Statler-Hilton Hotel, Cleveland, Ohio.

May 24-29, 1959 — National Association of Electrical Distributors (51st Annual Convention), Conrad Hilton Hotel, Chicago, Ill.

May 26-30, 1959 — Pacific Northwest Regional Conference, Banff Springs Hotel, Banff, Alta.

June 4-5, 1959 — Northeastern Regional Conference, Curtis Hotel, Lenox, Mass.

June 11-12, 1959 — Canadian Regional Conference, Chateau Laurier, Ottawa, Ont.

June 18, 1959 — Council Meeting, Illuminating Engineering Society, New York, N. Y. Members are free to attend meetings of Council as guests.

June 22-23, 1959 — Great Lakes Regional Conference, Lafayette Hotel, Buffalo, N. Y.

June 22-26, 1959 — American Institute of Electrical Engineers, Summer and Pacific General Meeting, Seattle, Wash.

October 5-10, 1959 — Society of Motion Picture and Television Engineers, Hotel Statler, New York, N. Y.

October 12-14, 1959 — National Electronics Conference, Inc., Hotel Sherman, Chicago, Ill.

October 12-16, 1959 — American Institute of Electrical Engineers, Fall General Meeting, Chicago, Ill.

October 19-20, 1959 — Annual Meeting of the United States National Committee (C.I.E.), Nittany Lion Inn, State College, Pa.

November 2-5, 1959 — Eleventh Exposition of the Air-Conditioning and Refrigeration Industry, Convention Hall, Atlantic City, N. J.

November 9-13, 1959 — National Electrical Manufacturers Association, Traymore Hotel, Atlantic City, N. J.

Engineering Enrollment Drops — First Time in Seven Years

Despite the still critical demand for engineering talent in the United States, accredited American engineering colleges had 2.9 per cent fewer students in the fall of 1958 than in the fall of 1957, with this year's freshman class 11.6 per cent smaller than the previous one. These figures, from an official survey conducted by the American Society for Engineering Education in cooperation with the U. S. Office of Education, indicate that for the first time in seven years there has been a decrease in undergraduate enrollments.

A sharp increase, however, is noticeable in the number of students engaged in graduate study — 14.7 per cent more Master's candidates this year, and 14.3 per cent more Doctoral students.

Electrical engineering is the most popular field with both the undergraduate

(*Continued on page* 20A)

Gibson Ortho 88

PATENT PENDING

THE FIXTURE THAT JUST PLUGS IN

snap - and it's up! **ortho-88**

Made in 48" and 96" lengths for the following lamps:

Rapid Start
Slimline
800 ma R. S.
Power Groove
VHO and SHO

All fixtures, except the 40 w. Rapid Start, are interchangeable on the Uni-Race with all other fixtures of the same length.

4 SIMPLE STEPS

THAT SAVE OVER 75% IN INSTALLATION TIME

Contractors report that all labor, including rods or stems and lamping, for a Gibson Ortho installation averages only 17 to 22 man-minutes per fixture, as compared with the NECA standard of over 2 man-hours for conventional fixtures.

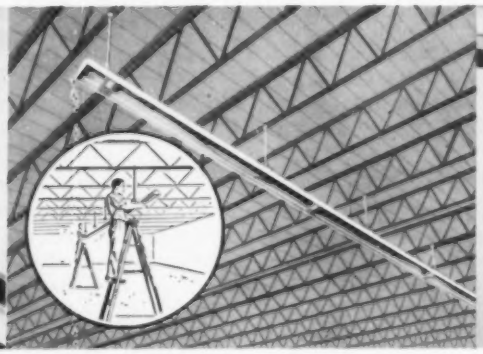
1 **Assemble the Uni-Race** • The exclusive Gibson Raceway known as the Uni-Race can be assembled on the floor in lengths up to 48 feet. The four or eight-foot sections are joined by telescoping couplers which provide a smooth, rigid union of the sections and are fastened with self-tapping screws.

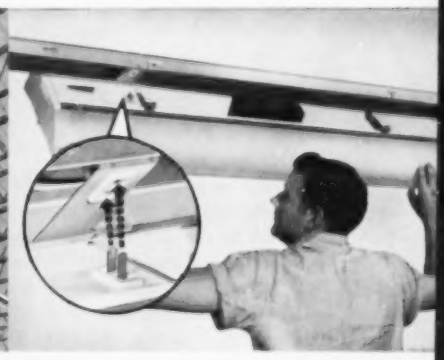
WRITE FOR COMPLETE INFORMATION ABOUT THE GIBSON ORTHO LINE

Gibson LIGHTING

Add, remove, re-space fixtures any time without tools or rewiring

The unique design of the Gibson Ortho, with its exclusive Uni-Race, makes it the world's most versatile fixture. Instead of being wired permanently to the branch circuit, it simply plugs in—like an appliance. A plug built into the fixture engages a receptacle in the Uni-Race, and since the receptacles are positioned at 48″ or 96″ fixture intervals along the Uni-Race, spacing of the fixtures is automatic. They can be mounted in continuous rows or spaced at intervals of 4, 8, 12 or more feet. Fixtures can be added or removed any time, according to the requirements of plant layout. Such changes need no electrical work whatever. They can be made by one man without tools. Think what this saves the owner whenever the lighting layout has to be re-arranged or when a fixture must be removed for repairs or cleaning!





2 Wire the Uni-Race • Branch-circuit wires are laid in the Uni-Race and connection is made at each built-in receptacle. The receptacles will later receive the plug that is built into each fixture. The Uni-Race is U.L. approved as a raceway with a capacity of five No. 8 AWG wires or eleven No. 14 wires.

3 Hang the Uni-Race • The rigid Uni-Race is easily lifted and hung in any of several different ways. Lengths up to 48′ can be hung as a unit if supported every 24′ while being raised to mounting position. When the branch-circuit connection is made, the Uni-Race is ready for the fixtures.

4 "Plug In" the Fixtures • The fixtures are merely "plugged in" on the Uni-Race. Hooks on the fixture engage in slots on one side of the Uni-Race, acting as hinges. The fixture is swung closed and latched. The built-in plug on the fixture automatically connects with the receptacle in the Uni-Race.

GIBSON MANUFACTURING COMPANY

1919 PIEDMONT CIRCLE, N.E. **ATLANTA 9, GEORGIA**

Manufactured in Canada under franchise by Electrolier Manufacturing Co., Ltd., Montreal

(Continued from page 17A)

and graduate students, with mechanical and civil engineering following in that order for the undergraduates. Among those studying for advanced degrees, chemical engineering is second, and mechanical third.

Women comprise less than 1 per cent of the total 1958-1959 undergraduate enrollments.

George H. Stickney Fund Established

The IES Council, at its February meeting, recorded by unanimous vote a resolution in memory of George H. Stickney, whose long career in the lighting art and the Society was ended by death last December 19.

Immediately following this action, Council officially accepted the fund which was started by Mr. Stickney's many friends and associates. Nucleus for the fund is the group of checks sent in lieu of flowers, at the time of the funeral services. Other friends wishing to add to this fund may send checks to IES Headquarters.

It is anticipated that plans for the use of the fund will be developed shortly in such appropriate areas as a memorial library or an award for achievement in the Society or lighting field generally.

Street Lighting Panel To Visit Four Western Cities

A traveling panel of four street lighting experts, each from a different company will keynote street lighting meetings in four western cities this spring. This program, arranged by the Street Lighting Committee of the Golden Gate Section brings the speakers to Los Angeles on April 21, San Francisco on April 23, Seattle on April 27 and Salt Lake City on May 1.

The traveling panel is somewhat of an innovation in IES circles and it is hoped that the program will provide those attending the meetings with a glimpse into the latest street lighting developments. The committee believes that the organization of this two-week tour enabled them to secure more key men for the panel than would have been possible had four uncoordinated section meetings been planned.

Each panel member has been assigned a topic for discussion in order to provide comprehensive coverage of the field. Panel members and their topics are: J. H. Fahey, Joslyn Manufacturing Co. — Incandescent Lighting; E. B. Karns, Westinghouse Electric Co. — Mercury Vapor Lighting; K. D. Tobin, General Electric Co. — Fluorescent Street Lighting and W. B. Blackford, Line Materials Industries — Street Lighting Circuitry.

Members of Sections and Chapters in the surrounding areas have been invited to attend the sessions.

Refresher Course Offered In Eastern Pennsylvania

A refresher course in lighting applications is being given in seven Pennsylvania cities under the joint auspices of the Eastern Pennsylvania Section of IES and the General Extension Division of the College of Engineering and Architecture of The Pennsylvania State University. The course is intended for drafting and design personnel of architectural firms, lighting and maintenance engineers, utility sales personnel, retailers of lighting equipment, electrical contractors and manufacturers who have previously completed a basic lighting course and now wish to learn about the latest developments and techniques in the illumination field.

Classes meet for 12 two-hour periods, with three of the sessions consisting of lectures and demonstrations and the remaining nine using the problem-conference approach. The course is being given in Allentown-Bethlehem-Easton (classes in Allentown), Harrisburg, Lancaster,

(Continued on page 23A)

George Hoxie Stickney — International Lighting Engineer

Within the past three decades, the lighting industry in the United States, through the U. S. National Committee of the Commission Internationale De l'Eclairage, has taken an ever increasing interest in lighting on a world-wide basis. At the fore in leading the United States participation, George Hoxie Stickney rendered such effective service that he was known as "Uncle George" wherever lighting men assembled.

Quickly he sensed the new problems which faced American lighting men entering international committee activities, such as the difficulty in translating some expressions from one language to another. He was quick to recognize that European scientists and inventors, in fact, those from all nations, are in no way inferior to their American counterparts. George Stickney knew that international cooperation is a two-way street.

In Bellagio in 1926, in the United States in 1928, in England in 1931, Germany in 1935 and Holland in 1939, his wise counsel and patient efforts did much to bridge the differences in languages and personalities. Typical of "Uncle George's" character was his action in 1935 of giving up the Presidency of the U.S.N.C. and returning to the position of Secretary-Treasurer because he felt that arrangement would be more favorable all around.

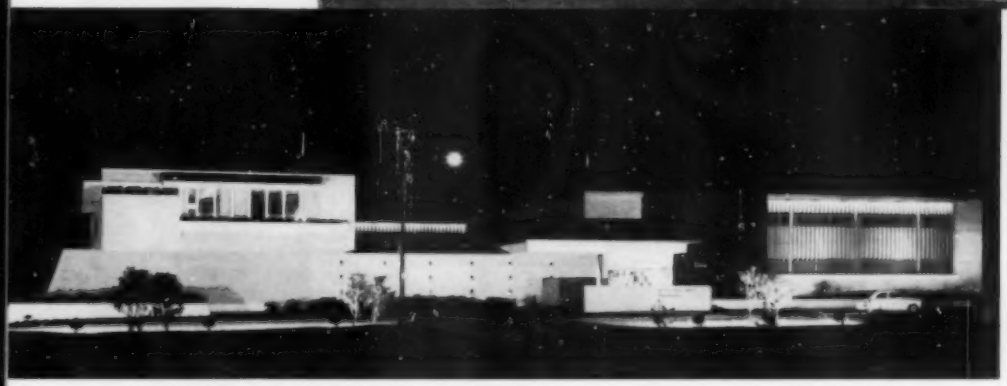
The adoption of the present five-part classification of luminaires was due, in no small degree, to George Stickney's efforts. Before that system was agreed upon, the United States was using a three-part classification, Japan was using a fourteen. Other nations varied between these two extremes. So effective was the compromise that the new five-part system was accepted throughout the world within a very short time.

After the 1939 C.I.E. Convention in Scheveningen, Holland, Germany assumed the task of publishing the Proceedings. With the outbreak of World War II, however, all action in this quarter was suspended. The U. S. National Committee *did* have access to a duplicate set of records in Holland, and with "Uncle George" as editor the U.S.N.C. prepared a one-volume English language version of the *Proceedings*. This exceptional piece of editorial work remained the only published record of the 1939 sessions until after the close of the war. It was the first international record of any international sessions published entirely in English, and did much to stimulate world-wide interest in lighting matters in the U. S.

George Stickney was truly a dedicated engineer and scientist, and he maintained an active interest in the work of the U.S.N.C. until a short time before his death.

ARTHUR A. BRAINERD
Executive Sub-Committee, U.S.N.C.

Decorative and security lighting for the Administration Center of Dow Chemical Company's Texas Division is achieved through use of 15 Wide-Lites placed around the building.



Wide-Lite Model F-400-AWB

creative lighting calls for **WIDE-LITE**

Dramatic lighting effects are easily achieved when Wide-Lites are selected as the lighting engineer's basic tool.

Designed especially to enhance the unique characteristics of color-corrected mercury vapor lamps, Wide-Lites bring *new dimension* to decorative lighting. They produce broad patterns which may be overlapped to provide smooth, even coverage without concentric circles, hot spots, or dark shadows to mar the architectural harmony of a building. The patterns are unusually uniform and may be accurately plotted to determine the exact number of units needed to provide any desired illumination level.

Ruggedly constructed from cast aluminum alloy, Wide-Lites are finished in aluminum epoxy paint for corrosion control. All outdoor models are sealed with tempered glass lenses, and relamping is accomplished without disturbing the seal of the lens. Exclusive built-in heat radiating fins limit lamp temperatures to the most efficient range. Sizes range from 100-watt to 1000-watt, and a choice of reflectors is available on all models.

To assist you in planning dramatic decorative lighting effects, Wide-Lite engineers have prepared a unique group of transparencies which read directly in Wide-Lite beam footcandles. Write today for your set . . . and a copy of Catalog 444 which gives information on the complete Wide-Lite line of indoor, outdoor and special application fixtures.

WIDE-LITE.

Manufactured by

WIDE-LITE CORP.

P. O. Box 191 • Houston 1, Texas

IN CANADA: WIDE-LITE DIVISION OF WAKEFIELD LIGHTING, LIMITED • LONDON, CANADA

THE MOST COMPLETE LINE

of indoor mercury lamp ballasts in the industry

PRIMARY VOLTAGE RANGES AVAILABLE*				
LAMP WATTAGE	JEFFERSON	BRAND A	BRAND B	BRAND C
1-100 watt	4	1	NONE	NONE
1-175 watt	4	NONE	NONE	NONE
1-250 watt	4	1	NONE	NONE
1-400 watt	4	4	4	2
1-400 watt Low Temp.	4	NONE	1	1
2-400 watt	4	4	NONE	3
1-700 watt	3	NONE	NONE	3
1-1000 watt (H12)	4	4	NONE	3
1-1000 watt (H15)	3	3	NONE	1
CONSTANT WATTAGE				
1-100 watt	4	NONE	NONE	NONE
1-175 watt	4	NONE	NONE	NONE
1-250 watt	4	NONE	2	NONE
2-250 watt	NONE	NONE	2	NONE
1-400 watt	4	NONE	5	NONE
2-400 watt	4	NONE	6	NONE
1-700 watt	4	NONE	4	NONE
1-1000 (H12)	4	NONE	4	NONE
1-1000 (H15)	4	NONE	5	NONE

*Per published information 2/15/58

COMPARE THE HIGH-POWER FACTOR ENCLOSED BALLASTS AVAILABLE AS STANDARD CATALOG ITEMS

Check these Jefferson Plus Features

(STANDARD ON MOST MODELS)

- √ Full light output
- √ Proper taps for voltage ranges
- √ Two roomy wiring compartments
- √ Combination wall and pendant mountings
- √ Color-coded leads
- √ Easy-to-read diagrammatic name plates

FAST DELIVERY

from the most complete stock in the industry

Jefferson ELECTRIC COMPANY

Bellwood, Illinois

(Continued from page 20A)

Reading, Scranton, Wilkes-Barre and Williamsport.

The program is divided into three general groups of topics:

The Tools of Industry — Luminous elements; cold cathode design and principles; fluorescent lamp circuits; electric wiring.

Using the Tools — Luminous ceilings; school and office lighting; general exterior lighting; industrial lighting; mood lighting and residential lighting.

Keeping the Tools Sharp — Economics of lighting; maintenance; frauds in lighting; need of lighting knowledge and need of new ideas.

Dr. Arthur Brainerd, recently retired from the Philadelphia Electric Co. and at present a member of the Executive Subcommittee of the U. S. National Committee of the C.I.E., is the keynote speaker in the program and will visit each class three times during the course. Other instructors are F. M. Gochenauer, Training Director; P. H. Hildebrand, Technical Consultant; E. W. Kelsey, Lighting and Wiring Specialist; J. M. McMillen, Illuminating Engineer and P. A. Sweet, Supervisor of Business Sales, all of the Pennsylvania Power & Light Co., and A. J. Fladd, Electrical Engineer, Roushey, Smith and Ulhman, Engineers and Architects.

Enrollment fee for the course is $30.

From the Desk of the President

Let's discuss the Society's publications program. Most readers may feel they already know all about this — after all, they get IE every month. They buy the new Handbook as it comes along, and they have a well-stocked library of IES committee reports. But how does all this happen?

The answer is, it doesn't "just happen." The Society has a very efficient setup of committee assignment plus professional staff. Here's how it works:

Papers Committee — This committee is assigned the responsibility of procuring papers for the annual National Technical Conference. Since the papers accepted for the Conference program are also submitted for possible publication in the Society's journal, this committee, as you can see, is closely linked with the Society's publication program. The Papers Committee has the decision also, of stating which of the Conference papers shall be designated as Transactions of IES, and which not. Papers designated as Transactions have mandatory publication in IE. Although the Papers Committee has responsibility only for the procurement, review and approval of Conference papers, they also serve as a "review board," upon request of the editor, for any technical paper submitted for publication by the Society.

This year, Chairman of the Papers Committee is Floyd W. Sell, Detroit Edison Company. His committee has just recently finished the arduous task of appraising the scores of conference paper outlines — from members who would like to present papers at San Francisco. Out of dozens and dozens of outlines considered, the program of perhaps 35 papers is decided — and then the committee commences its even more arduous task of studying and reviewing each and every manuscript before approving its publication as a preprint to be shipped to San Francisco. The papers will be reviewed again, after the conference, for approval as a Transaction of IES.

Publications Committee — Council designates to this committee the responsibility of producing all of its published material — a monthly magazine, various committee reports and booklets, and, at intervals, a Handbook. They are, in effect, a Board of Directors for a publishing business, and as such concern themselves with the budget and finances of the publications program, editorial policy, procurement of material, and numerous other phases of a publishing business. Dr. Rolland M. Zabel is the current chairman. Several subcommittee chairmen devote themselves to such problems as Data Sheet procurement (and review), publication sales, changes and improvement, etc.

Professional Staff — With a business so complicated and specialized as publishing, obviously professional people are required to carry out the actual program. It may be a surprise to many members that all of the phases of the publications program, editorial and sales, are carried out by only eight people. It is a tribute to their professional skill that month after month, they produce — and on time — a major 120-page magazine which has been rated as tops in the magazine field — and dozens of separate publications as well. You may be interested in knowing who these people are:

Editorial Office

Editor — Ruby Redford. Most of you know Ruby. You've seen her at dozens of Regional and National conferences, collecting material for a report, taking spot news pictures with that two-ton Speed Graphic of hers, or button-holing engineers for details of an outstanding lighting job. These raw details may eventually come forth as a smoothly written article. She goes to great lengths

(Continued on page 26A)

"IT'S THAT NEW SWEDISH MODERN STYLE!"

Howard Jasnau

LUMINAIRE MANUFACTURERS

if you order this...

flex-line

The revolutionary new fluorescent lampholder

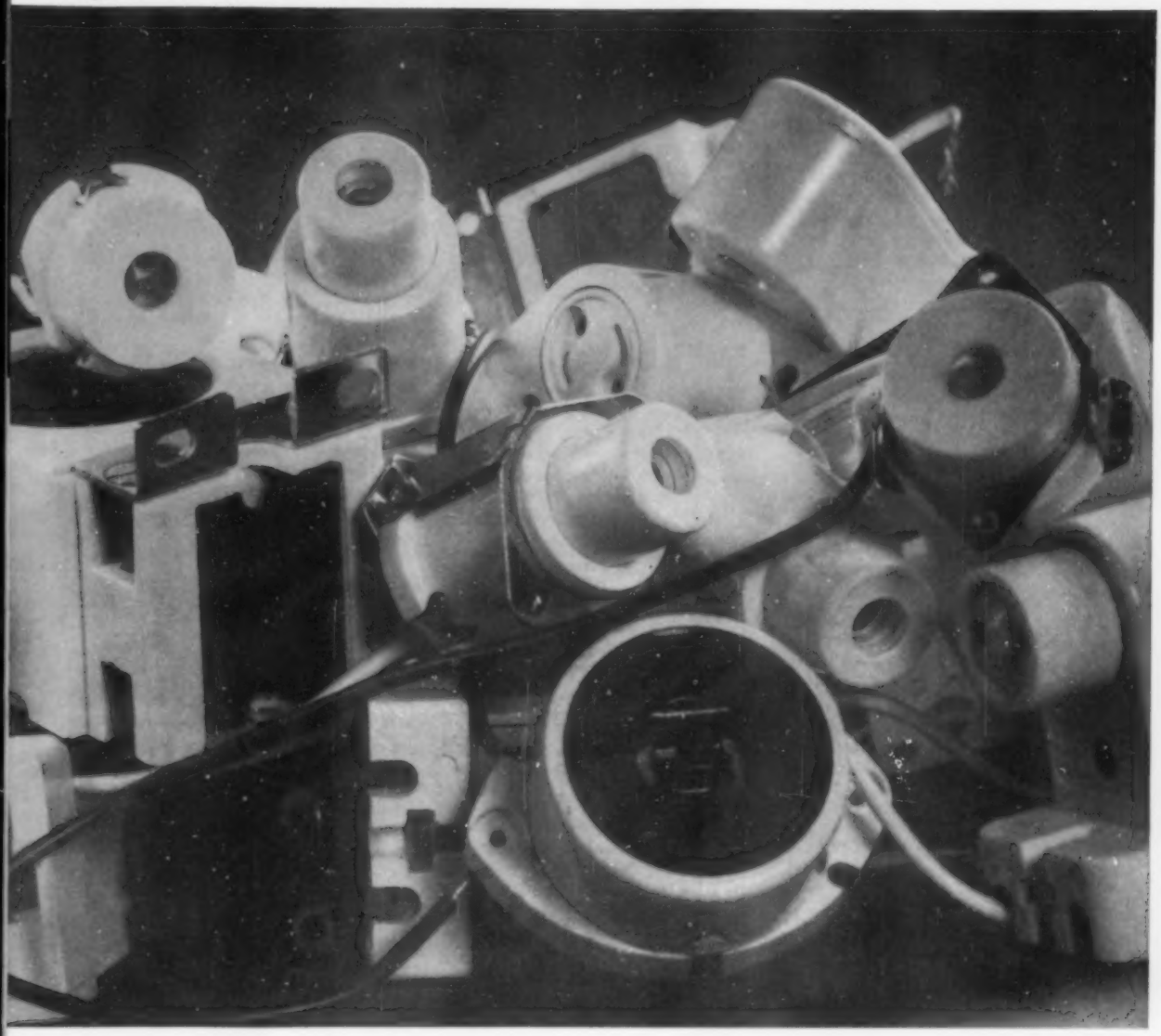
Interchangeable plungers with identical external configurations and mounting dimensions fit one basic bracket. *One* lampholder provides for *all three* lamps—Bi-Pin, Slimline or Protected Terminal.

Superior Flex-Line Features

Lampholders can be replaced in the field without removing end plate or lowering fixture.

Silver plated contacts welded directly to wire leads.

you don't need these!



Plunger springs do not carry current; maintain positive, sure contact; keep lamps vibration-free.

No safety clips required to hold lamps in position.

Flex-Line is ideal for use on outdoor sign applications.

Another exclusive from Bryant—a *weatherproof unit* adaptable for Protected Terminal, Slimline and Bi-Pin lamps.

Flex-Line is creating considerable interest among luminaire manufacturers, and after you have talked with your Bryant Sales Representative, you'll see why. Contact him, or write: The Bryant Electric Company, Bridgeport 2, Connecticut. J-99009

ANOTHER FINE PRODUCT FROM THE NEW BRYANT

BRYANT

THE BRYANT ELECTRIC COMPANY
BRIDGEPORT 2, CONNECTICUT

(Continued from page 23A)

to "feel out" what the readers want or need, and to go get it for them and/or write it for them. Whenever you know of an interesting lighting installation, or a technical study, just let Miss Redford know about it. She'll take it from there.

A full Member of IES, Miss Redford is also a member of New York Business Papers Association, the American Institute for Graphic Arts, the National Society for Interior Design and is a Member-At-Large of the USNC of the Commission Internationale de l'Eclairage.

Editor's Assistant — Barbara Lamson. A highly-trained professional in magazine work. Skilled at writing from "raw material," layout display, magazine production details and the zillions of things that happen in publication work. A graduate of Swarthmore, Miss Lamson is a whizz at math as well as magazine production.

Editorial Assistant — Barbara Marwell. "Bobbie" has only been with IES a year, but already she is highly skilled in magazine production, layout, re-write and news writing. She majored in this kind of thing at Barnard. Another real pro.

Editorial Secretary — Alice Stevens. Secretarial work in the editorial field takes a very special kind of experience. This job calls for a combination of secretarial efficiency and editorial assistance. We have both in good measure in Mrs. Stevens. You see one of her projects every year, when you get that comprehensive Index to IE, in January, indexing every subject covered for the year, every author, and every committee member including all his assignments, and even his address. A monumental job of organization.

Advertising and Publication Sales

Advertising and Promotion Manager— Clayton E. Ellis. Here's another well-known member of the senior staff. He has a professional degree in journalism, is a member of National Industrial Advertisers Association, and has many years of successful experience in the advertising field. Clayt's good job for IE advertising (which makes the whole thing possible in the first place) comes to your attention with every issue. But did you know that he also promotes the distribution and sale of *all* IES publications? Currently he's up to his eyes in the extra job of selling the new Handbook, and has as well sold the manufacturers data section in it. So far it looks as though this will have to go right back on the press for an additional run, as soon as it's printed, to meet the demand.

Advertising Assistant — Adelaide (Sally) Philiba. A pro to the core, with a degree in advertising from the University of Illinois. Have you ever stopped to think how ad plates get placed so the color runs are on the proper forms; how two-color plates get matched up right; how many tricky details there are in working out an imposition? All to a deadline? This is only one phase of this job, of course, but it gives you an idea.

Staff Assistant — Florence Meyers. Hundreds of orders come to Clayt's department, for the many different IES publications. Miss Meyers is the staff member who handles them. Right now, the whole Publications Sales staff is snowed under with the Handbook orders (on top of reprint orders). This is the tail end of the busiest season for Florence because her job includes the handling of non-member subscriptions. Miss Meyers will, with all other members of the sales staff also soon be occupied with invoicing Handbook orders.

Secretary — This job is temporarily looking for the right girl. The amount of correspondence handled in this department is really tremendous and if it remains unstaffed very long, look for dark circles under Clayt's eyes.

If the Society's publication program seems to you to be "automatic" let me remind you that the more effortless an operation appears, the more organization and know-how is behind the scenes.

GEORGE J. TAYLOR
IES President

ABOUT PEOPLE

Three new regional sales districts have been established by Corning Glass Works to service their Technical Products Division, according to a recent announcement. The new districts and their respective sales managers are: Central District, **Hugh L. Kline,** with headquarters in Chicago; Eastern District, **Donald Pisula,** headquarters in New York City and Southern District, **Kenneth D. McNeil,** headquarters in Houston, Texas. **Clair W. Van Etten** continues as Western District sales manager with offices in Los Angeles. The company has also announced appointments of product engineering supervisors in each of four sales departments: **William F. Crosby,** Lighting; **William M. Baldwin,** Plant Equipment; **Warren L. Price,** Optical; and **Richard A. Petty,** Laboratory Glassware. In another organizational change, **Jerrold R. Bucher** has been promoted from field sales manager of the Laboratory Glassware Department to assistant manager of the department.

Irwin A. McMath, Pacific Gas & Electric Co., Fresno, Calif., received the annual Award of Merit presented by the Central California Optometric Society to a person outside that organization. Mr. McMath was honored for his work in the formation of the Yosemite Chapter of IES of which he is charter chairman.

Revere Electric Manufacturing Co., Niles, Ill., has announced the election of **John A. McDougall** as vice-president in charge of sales and **C. M. Schultz** as secretary and assistant treasurer.

Donald L. Millham, a vice-president of General Electric Co. has been named consultant to the company's Lamp Division, it was announced by **James H. Goss,** vice-president and group executive of the Consumer Products Group. Vice-president **George E. Burens,** former general manager of the Switchgear and Control Division in Philadelphia succeeds Mr. Millham as general manager of the Lamp Division in Nela Park. **Lewis J. Burger** has been appointed to succeed Mr. Burens. Prior to this appointment, Mr. Burger was general manager of the Gas Turbine Department in Schenectady, N. Y. All three appointments were effective January 26.

Frederick Keller, president of Thomas Industries, Inc., Louisville, Ky., has announced the new officers of Benjamin Electric Manufacturing Co., Thomas' recently acquired subsidiary. Mr. Keller will serve as president of Benjamin, with **John G. Beam** as executive vice-president, **George A. Hamm** as vice-president, **Arthur E. Swedenborg** as vice-president in charge of sales, **Ray H. Mathison** as secretary and **Robert K. DiVall** as treasurer. Mr. Beam and Mr. Mathison are also vice-president and secretary, respectively of Thomas Industries. Also announced by Thomas was the promotion of **Robert C. Gand** to district manager of the company's lighting division in the Chicago area. Mr. Gand is membership chairman of the IES Chicago Section's Residence Lighting Forum and a member of the Chicago Lighting Institute's Residence Lighting Committee. He was formerly a sales representative and lighting specialist for Thomas in Chicago.

McPhilben Lighting Inc., Brooklyn, N. Y. has announced the promotion of **Edward L. Gluck** from New York sales manager to Northeastern regional sales manager, with responsibility for sales to architects and engineers from Maine to Maryland. The appointment was effec-

(Continued on page 31A)

NOW! the most powerful fluorescent you can buy!

15,000 LUMENS

GENERAL ELECTRIC POWER GROOVE LAMP

the arc of a 9-foot lamp in an 8-foot tube

LOWER COST OF FLUORESCENT LIGHT

If you are planning a new building or remodeling your present one, General Electric's new Power Groove Fluorescent Lamp is your best lighting buy. Imagine—a single 8-foot fluorescent that delivers a startling 15,000 lumens! Virtually twice as much light as the next most powerful G-E fluorescent.

LOWER CAPITAL INVESTMENT... LOWER MAINTENANCE COSTS

Here's the most significant part of the new G-E Power Groove story. With all the light it delivers, you can enjoy lighting levels not as practical with other fluorescents because of the number of lamps required. To duplicate the lighting level of a typical Power Groove installation with less powerful fluorescent lamps could easily require a 20% *greater* investment!

TURN PAGE FOR THE INSIDE STORY OF THE G-E POWER GROOVE

MAKE YOUR NEXT LIGHTING STEP A BIG ONE. The biggest! When you design your new lighting system, take advantage of the economies of new G-E Power Groove Lamps. Ask your G-E Distributor about them. New G-E Power Grooves are available in 4′, 6′ and 8′ lengths to fit your present Power Groove fixtures. Or write: General Electric Co., Large Lamp Dept. C-912, Nela Park, Cleveland 12, Ohio.

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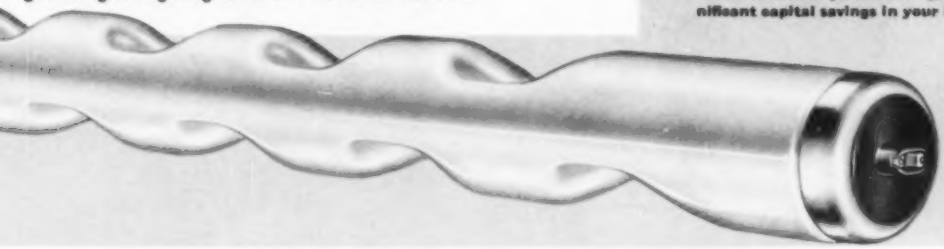
LOWEST COST OF FLUORESCENT LIGHT for most users...made possible by new

G-E POWER GROOVE

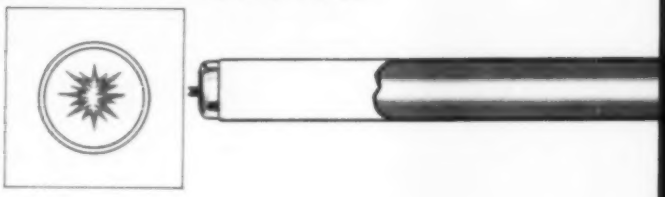
...and the secret's in the shape—a dramatic milestone in glass technology that enables you to convert *more electric power to light* in the same length lamp! You get a higher lighting level at a lower investment.

DEVELOPMENT ENGINEERS Bernard Shaw (left) and Clarence E. Hahn of G. E.'s Lamp Glass Dept. They guided the group that translated laboratory development of new Power Groove to production quantities, bringing you significant capital savings in your lighting system.



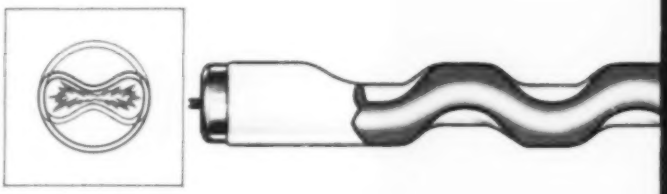
WHY THE GROOVES MAKE A DIFFERENCE

REGULAR FLUORESCENT in the conventional round shape has a straight arc stream. As in the case of any fluorescent, the arc causes mercury-vapor to produce radiation which excites the phosphor coating along the inside wall, which in turn fluoresces to give off light.



ORIGINAL POWER GROOVE FLUORESCENT, developed by General Electric in 1956, has a groove along one side of the tube, continuous except for bridging at regular intervals to increase glass strength. Resulting grooves or panels place phosphor closer to the center of the arc stream and "squeeze" the arc for greater light-producing power.

NEW POWER GROOVE has grooves on opposite sides to accomplish the same desired "squeezing" effect without bridges, but in addition makes the arc travel in a wavy path to effectively *increase* its length, thus giving you greater efficiency and even higher light-producing power.



Progress Is Our Most Important Product

GENERAL ELECTRIC

TURN THE PAGE TO SEE THIS NEW SHAPE IN LIGHT

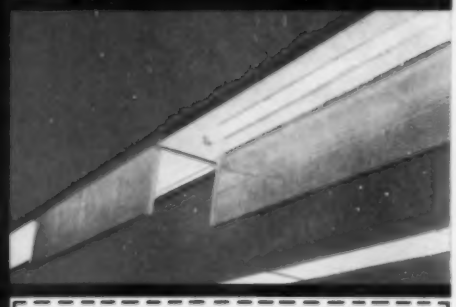
309-9

New Lighting Combination Installed by **Fischbach and Moore** Incorporated in their own quarters...

•

HOLOPHANE Prismalume* Controlens* in GLOBE "Miracle-Door"† Troffers

When one of the world's foremost electrical contracting firms chooses specific lighting products for its own use—that's noteworthy! Fischbach and Moore, Incorporated, installed GLOBE "Miracle-Door" Troffers equipped with the HOLOPHANE Lo-Brite* Prismalume Controlens in their recently occupied New York quarters... The prismatic Controlens, made of crystal-clear acrylic plastic, is one piece, 4-foot long. It directs color-true, maximum illumination to vital areas, minimizing brightness and glare... Globe "Miracle-Doors" hinge open from either side; the "Hi-V" reflector plates are also reversible. This instant flexibility accommodates the partitioning requirements typical of today's modular construction... Send coupon today!



HOLOPHANE Company, Inc.
342 Madison Ave., New York 17, N. Y.

GLOBE Lighting Products, Inc.
16 E. 40th Street, New York 16, N. Y.

*® †Pat. Pend.

HOLOPHANE CO., INC., 342 Madison Ave., N.Y. 17
Please send us data on: Prismalume Controlens in Globe "Miracle-Door" Troffers.

INDIVIDUAL .....
ORGANIZATION .....
STREET .....
CITY ..... ZONE ..... STATE .....

One

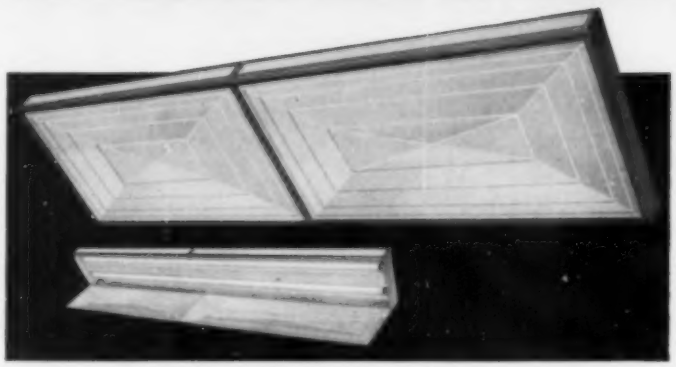
FOR THE MONEY!

The NEWTON Series is low in cost but big league in performance. Available with plastic louver or polystyrene lens; plastic sides. Newton offers unusual versatility for corridors, kitchens, stores, offices or playrooms. Newton fits compactly in narrow and limited areas. For 1 or 2 lamps.

Two

FOR SHOW!

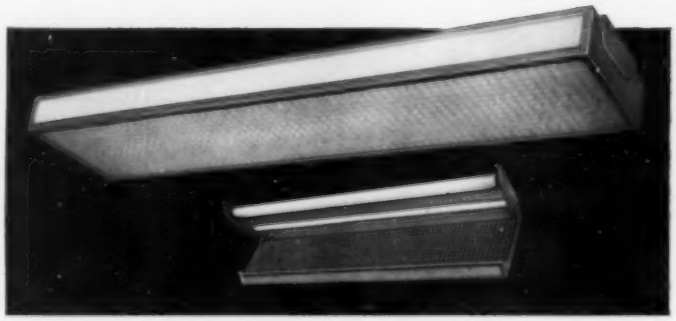
The shallow BOSTON Series makes a neat, clean-cut appearance. Less than 4" deep. Plastic louver or vinyl lens completely framed; hinged at both sides for quick relamping. Rigidly framed plastic sides cannot curl or warp. Available in 4' or 8' lengths for 2 or 4 lamps.



Three

READY AND ABLE . .

To turn in an outstanding performance. This shallow (less than 4" deep) CAMBRIDGE Series is available in 4' and 8' lengths for 2 or 4 lamps. The plastic louver or vinyl lens is instantly removed by finger-tip pressure to assure ease of maintenance.

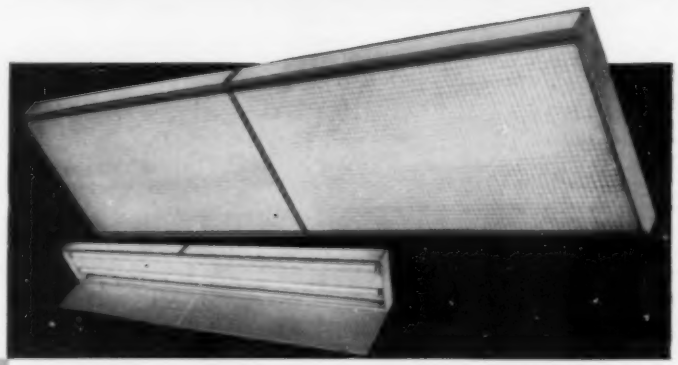


Four

GO MODERN . . .

With Eastern's sleek up-to-the-minute BROOKLINE Series, less than 4" deep. Plastic louver or vinyl lens is completely framed; hinged at both sides for ease of maintenance. In 4' and 8' lengths for 2 or 4 lamps.

This smart surface mounted group insures smooth, shadowless, glare free lighting. Full top reflector for peak lighting efficiency. Easy to install and maintain. Plastic louvers have 42° x 42° shielding. Units using 4 lamps over 24" wide . . . 2 lamps, over 12" wide.



Eastern

FIXTURE COMPANY

170 VERNON ST., BOSTON 20, MASS.

FIRST WITH THE NEWEST DEVELOPMENTS IN LIGHTING

Write for complete information on the Eastern line today

BEVERLY A. TRAVIS (left), Pacific Northwest Regional Veep, accepts his award from John Daniels of the Puget Sound Electrical League after being named "Electrical Man of the Year." Each year the League honors the individual in the Seattle-Tacoma area who has made the greatest contribution to the electrical industry. Mr. Travis, a Past-President of the Electrical League and the Engineers Club, was recently appointed electrical engineer for the Century 21 Exposition.

(*Continued from page* 26A)

tive February 1. Mr. Gluck is president of the Brooklyn Engineers Club and was a district engineer with Holophane Co. prior to joining McPhilben.

Theodore Summers, Jr. has been appointed lighting sales engineer for the Indianapolis area by Westinghouse Lighting Division. Mr. Summers, who served as an application engineer in the Lighting Division prior to this appointment, will make his office at the Westinghouse headquarters in Indianapolis.

Wilgar Coleman, editorial director of the Edison Electric Institute retired on February 1 after 35 years of service with the EEI and its predecessor, the National Electric Light Association. Succeeding Mr. Coleman is **Prall Culviner** who joined EEI's editorial department in 1948. Mr. Coleman had been responsible for the editorial and production aspects of all EEI publications since October 1923 when he began work with the National Electric Light Association as editor of the NELA *Bulletin*. Mr. Culviner served in various editorial capacities at the Institute from 1948-1953 when he left to become secretary and co-ordinator of Light's Diamond Jubilee celebration. In 1955, he joined the public relations department of Sylvania, and returned to the Institute in 1957.

Union Metal Manufacturing Co., Canton, Ohio, has announced the opening of a Mountain States District sales office in Denver, Colo., with **Clyde H. Cozadd** as manager. Mr. Cozadd will be responsible for sales in Colorado, Utah, Wyoming, Arizona and New Mexico. Pacific Union Metal Co., the firm's Los Angeles subsidiary has established a San Francisco sales office with **Charles G. Strom** as manager. This Northern California-Northern Nevada District will include that part of California north of Los Angeles, San Bernardino, Ventura and Santa Barbara counties, as well as northern Nevada.

Charles R. Wallace has been appointed Chicago Region sales manager of Curtis Lighting Inc., succeeding **Frank J. Bernd** who has become general sales manager of the firm.

Progress Manufacturing Co., Philadelphia, Pa. has named **David Weisberg** to the position of manager of advertising and sales development. Mr. Weisberg was formerly executive director of the Approved Kitchen Dealers of America and has been a marketing and sales promotion consultant for many firms.

Election of officers of the Society of Plastics Engineers for the current year were held on January 26th at the meeting of the Society's National Council. Elected were: President — **Fred C. Sutro, Jr.,** Spencer Chemical Co., Kansas City, Mo.; First Vice-President — **George W. Martin,** Holyoke Plastics Corp., Holyoke, Mass.; Second Vice-President — **Jules W. Lindau, III,** Southern Plastics, Inc., Columbia, S. C.; Secretary — **Frank W. Reynolds,** IBM Corp., Endicott, N. Y. and Treasurer — **Haiman S. Nathan,** Atlas Plastics, Inc., Buffalo, N. Y.

A. A. Bertrand was named Winnipeg Branch Manager for the Canadian Westinghouse Commercial Sales Division according to a recent announcement. Mr. Bertrand succeeded **S. M. Bolton** who had resigned.

Owens-Corning Fiberglas Corp. has named **Robert R. Hanna** as electrical sales engineer for the Central Great Lakes and Mid-Continent territories. Mr. Hanna, formerly a salesman in the company's Philadelphia office will now have his headquarters in Chicago where he will be responsible for promotional and engineering sales to electrical equipment manufacturers. In addition, he will serve as representative and specialist for the company's new polarizing light panel.

The Board of Governors of the Society of Motion Picture and Television Engineers has elected **G. Carleton Hunt,** General Film Labs., Hollywood, Calif. as financial vice-president to complete the unexpired term of SMPTE executive vice-president **J. W. Servies,** National Theatre Supply Co., New York, N. Y. **S. P. Solow,** Consolidated Film Industries, Hollywood, was chosen as the new treasurer of the Society, replacing **Reid H. Ray,** Reid H. Ray Film Industries, St. Paul, Minn. Mr. Reid is now convention vice-president of the SMPTE. Also announced was the appointment of former newspaper editor **Barbara D. Skeeter** as Director of Public Relations, succeeding **Wallace Shapiro.**

Quadrangle Manufacturing Co., Chicago, Ill. has announced the appointments of the following as sales representatives: **McGillan** Sales Co., Albuquerque, N. M., for New Mexico and the west end of Texas; **Robert W. Fishburne,** Richmond, Va., for Virginia and **W. J. Childers,** Dallas and **Robert Putterman,** Houston, for all of Texas with the exception of El Paso and the surrounding area.

Bertrand J. Farrell has been named general sales manager of the Jefferson Electric Co., Bellwood, Ill., with complete responsibility for the activities of the Consumer and Industrial Sales Divisions of the company. Replacing Mr. Farrell as distributor sales manager is

(*Continued on page* 52A)

NEW COOL SOLA SLIMLINE BALLAST

Sola ballasts guard your reputation with coolest coils and capacitors, easily pass "in-fixture" heat tests

Sola's new 650-110 ballast for two F96T12 or two F72T12 slimline lamps offers premium performance at only slight additional cost. This new CBM-certified ballast was tested in a totally-enclosed, four-lamp fixture mounted against fibrous acoustical material. Room ambient was 25°C. Maximum temperatures recorded were: case "hot spot" 86°C, capacitor 70°C. Each temperature was well within insulation limits and U.L. fixture requirements. Sola outperformed competitive, premium-priced ballasts tested under these same severe conditions. (Request Bulletin FL-356 for details and test results.)

Men who install, furnish, or specify fixtures know that "in-fixture" ballast performance is what really counts to the man who's buying the light and who insists on every lumen he's paying for. They know that Sola's all-CBM-certified ballasts give trouble-free, cool, efficient service . . . full light output and full ballast life.

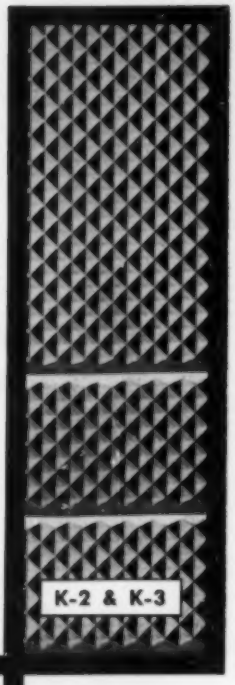
Fixture manufacturers are invited to evaluate this new, cool slimline ballast (Cat. No. 650-110) in their own fixtures. Request test samples or Bulletin FL-356 from ***Sola Electric Co.,*** A Division of Basic Products Corporation, ***4633 W. 16th Street, Chicago 50, Illinois.***

Now Available

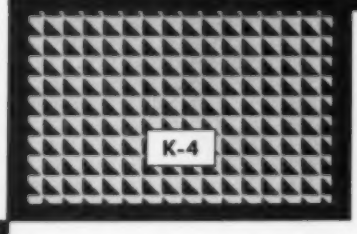
Ballast Catalog No. 650-110
for two F96T12 or two F72T12
430 ma slimline lamps

Write for Data

DON'T PAY FOR WASTE ...USE K LITE*



WATCH FOR NEW LENS PANEL K-5



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(Continued on page 38A)

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(Continued on page 40A)

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(Continued on page 42A)

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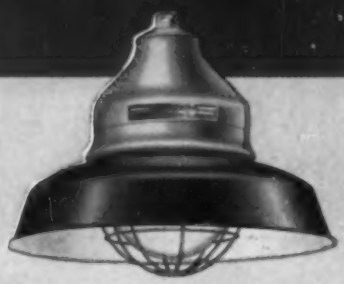

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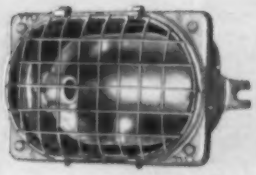

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(Continued on page 44A)

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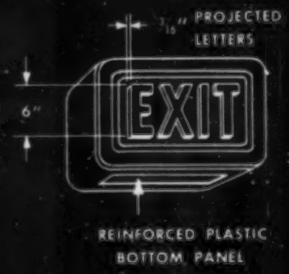

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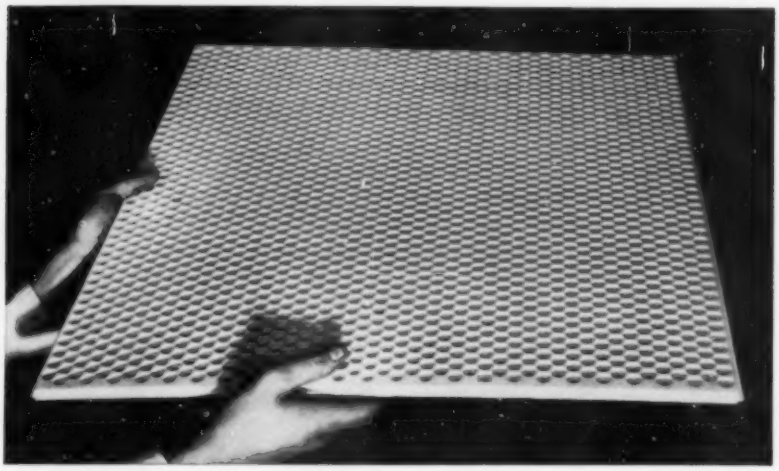
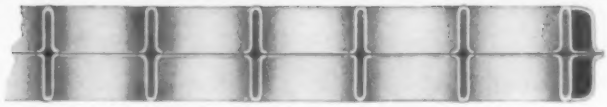
(Continued on page 46A)

CIRCLGRID

Non-Burning Vinyl Louver — A new luminous rigid panel for the Lighting Industry



CROSS SECTION THRU "CIRCLGRID" PANEL



Dimensions 23 ¾" square by ½" deep.

Showing how top and bottom vacuum formed vinyl sheets are electronically welded to a center membrane, creating a hermetically sealed unit with *great structural strength.* Circular inverted cone openings at every ½ inch assure non-glare illumination.

Other sizes in preparation.

Advantages of Rigid "Circlgrid" Panels

- will not support combustion
- are safely installed under sprinklers
- are lightweight and electronically welded for great structural strength
- are attractive
- offer controlled lighting in 300, 150 or 75 F.C. materials
- have 45° – 45° cut-off—other cut-offs in preparation
- have circular openings (50% open area) to promote air circulation and non-glare illumination
- have no flat spots to collect dust
- are rigid for easy installation and cleaning
- may be sawed or cut
- patent pending

While experimenting with many polyvinyl chloride formulations to produce a fire resistant luminous panel, we achieved far more in "Circlgrids". Of importance to lighting engineers is the controlled quality of non-glare light, ease of installation and reduced maintenance attained with "Circlgrid" Panels. Each panel consists of a pair of vacuum formed sheets of vinyl, hermetically sealed to a center membrane at every ½ inch. "Circlgrids" are designed with 50% open areas, each opening has small louvers to diffuse reflected light—there are no flat spots to collect dust.

"Circlgrids" are available in 3 material transparencies to provide 300, 150 or 75 F.C. They are light—stable and safely installed under sprinklers.

"Circlgrids" are easy to install in any inverted tee system of support and as easy to remove. They are designed to meet all code requirements.

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Pioneer in rigid, non-burning, luminous louver panels for ceiling lighting.

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P. O. Box 873
Cleveland 22, Ohio — *Robert K. Farrington*

Toledo Edison Co.
Edison Bldg., Toledo 4, Ohio — *William R. Poole*

Toronto Hydro-Electric System
14 Carlton St.
Toronto 2, Ont. — *Wilson J. Wylie*

B. M. Tower Co., Inc.
Dewey St., Bridgeport, Conn. — *Harvey N. Tower*

Trans-Lite, Inc.
P. O. Box 70
Milford, Conn. — *H. W. Jones, Jr.*

Tri-Part Mfg. Co.
934 Plum St., Detroit 1, Mich. — *Julius Reznik*

Union Electric Co.
315 N. 12th Blvd.
St. Louis 1, Mo. — *Merrill E. Skinner*

Union Metal Mfg. Co.
Canton 5, Ohio — *W. A. Porterfield*

Unistrut Corp.
4118 Monroe Ave.
Wayne, Mich. — *Hugo E. Rebentisch*

Unistrut Products Co.
1013 W. Washington Blvd.
Chicago 7, Ill. — *George W. Butler*

The United Illuminating Co.
80 Temple St.
New Haven 6, Conn. — *E. B. Haskell*

Universal Lighting Products, Inc.
55 Bergenline Ave.
Westwood, N. J. — *Elliott Kanarek*

Universal Mfg. Corp.
29-51 E. 6th St.
Paterson, N. J. — *Imrich Miller*

Utah Power & Light Co.
Box 899, Salt Lake City 10, Utah — *W. A. Huckins*

John C. Virden Co.
6009-6105 Longfellow Ave.
Cleveland 3, Ohio — *John C. Virden, Jr.*

John C. Virden Ltd.
19 Curity Ave.
Toronto 16, Ont. — *Cyril E. Brit*

Virginia Electric & Power Co.
Richmond 9, Va. — *W. I. Dolbeare*

Voigt Company
1634-38 N. Carlisle St.
Philadelphia 21, Pa. — *C. J. Frank*

Voltarc Tubes, Inc.
44 Cross St., Norwalk, Conn. — *Miles Pennybacker*

Wadeford Electric Co.
205 W. Wacker Dr.
Chicago 6, Ill. — *H. H. Lundberg*

The Wakefield Co.
Vermilion, Ohio — *A. F. Wakefield*

Wald & Zigas
23-03 45th Rd.
Long Island City, N. Y. — *Henry J. Wald*

Warren Electric Co.
P. O. Box 2594
Houston, Texas — *J. R. Thompson*

Wasco Products Inc.
Bay State Rd.
Cambridge 38, Mass. — *M. C. Kirkpatrick*

The Washington Water Power Co.
P. O. Drawer 1445
Spokane 6, Wash. — *Gordon F. DeFoe*

Webb Electric Mfg. Co.
1701 S. W. Jefferson St.
Portland 1, Ore. — *F. E. Webb*

Weisbach Engineering and Management Corp.
1500 Walnut St.
Philadelphia 2, Pa. — *H. H. Adams*

Westinghouse Electric Corp.
503 Amarillo Bldg.
Amarillo, Texas — *E. R. Price*

Westinghouse Electric Corp.
1216 W. 58th St.
Cleveland 2, Ohio — *E. C. Huerkamp*

Westinghouse Electric Corp., Lamp Division
Bloomfield, N. J. — *Marshall N. Waterman*

Westinghouse Electric Supply Co.
5 Gateway Center, P. O. Box 448
Pittsburgh 30, Pa. — *Joseph W. Hartman*

West Penn Power Co.
Cabin Hill, Greensberg, Pa. — *R. G. MacDonald*

Wheeler Reflector Co.
Division of Franklin Research Corp.
275 Congress St.
Boston 10, Mass. — *Harlan B. Fletcher*

Wheeling Electric Co.
51 Sixteenth St.
Wheeling, W. Va. — *M. J. Barth*

Dick White Lighting, Inc.
170 Southdale
Edina 10, Minn. — *Donald D. Olson*

White Way Electric Sign & Maintenance Co.
1317 Clybourn Ave.
Chicago 10, Ill. — *Martin Davis*

Wholesale Electrical Supply Co.
7333 Cottage Grove Ave.
Chicago 19, Ill. — *Raymond D. Arenberg*

Wide-Lite Corp.
P. O. Box 191
Houston 1, Texas — *D. L. Calmes*

Wiedenbach-Brown Co. Inc.
111 Eighth Ave.
New York 11, N. Y. — *W. C. Stockberger*

Wigdahl Electric Co.
4246-48 Milwaukee Ave.
Chicago 41, Ill. — *T. J. Wigdahl*

R & W Wiley Inc.
119 Dearborn St.
Buffalo 7, N. Y. — *Robert C. Graves*

H. E. Williams Products Co.
108 S. Main St.
Carthage, Mo. — *F. B. Williams, Jr.*

Wilmot Castle Co.
P. O. Box 629
Rochester 2, N. Y. — *E. H. Greppin*

J. A. Wilson Lighting & Display Ltd.
280 Lakeshore Rd.
Toronto, Ont. — *J. Carl Wilson*

The Windsor Utilities Commission
Hydro Division
149 Chatham St. W.
Windsor, Ont. — *Henry R. Soutar*

The Wiremold Co.
Hartford 10, Conn. — *Robert H. Murphy*

Wisconsin Electric Power Co.
Public Service Bldg.
Milwaukee 1, Wis. — *G. W. Van Derzee*

Wisconsin Power & Light Co.
122 W. Washington Ave.
Madison 1, Wis. — *M. R. Norton*

Wisconsin Public Service Corp.
Green Bay, Wis. — *A. G. Bur*

Worcester County Electric Co.
939 Southbridge St.
Worcester 5, Mass. — *Donald S. Bennett*

Work-O-Lite Co.
522 Cortlandt St.
Belleville, N. J. — *Jack Siegel*

Zenith Electric Supply Ltd.
185 Bridgeland Ave.
Toronto 10, Ont. — *B. R. Steen*

1959 Regional Conferences — I.E.S.

Region	Place	Date
East Central	Lord Baltimore Hotel Baltimore, Md.	April 9-10
South Central and Southeastern	Grove Park Inn Asheville, N. C.	April 23-24
Southwestern	Shamrock-Hilton Hotel Houston, Texas	May 4-5
Midwestern	Pere Marquette Hotel Peoria, Ill.	May 6-8
Inter-Mountain	Continental Hotel Denver, Colo.	May 11-12
Pacific Northwest	Banff Springs Hotel Banff, Alta.	May 26-30
Northeastern	Curtis Hotel Lenox, Mass.	June 4-5
Canadian	Chateau Laurier Ottawa, Ont.	June 11-12
Great Lakes	Lafayette Hotel Buffalo, N. Y.	June 22-23

VAN NUYS SAVINGS & LOAN ASSOCIATION, PANORAMA CITY, CALIFORNIA.
ARCHITECT & ENGINEER—BANK BUILDING & EQUIPMENT CORPORATION OF AMERICA

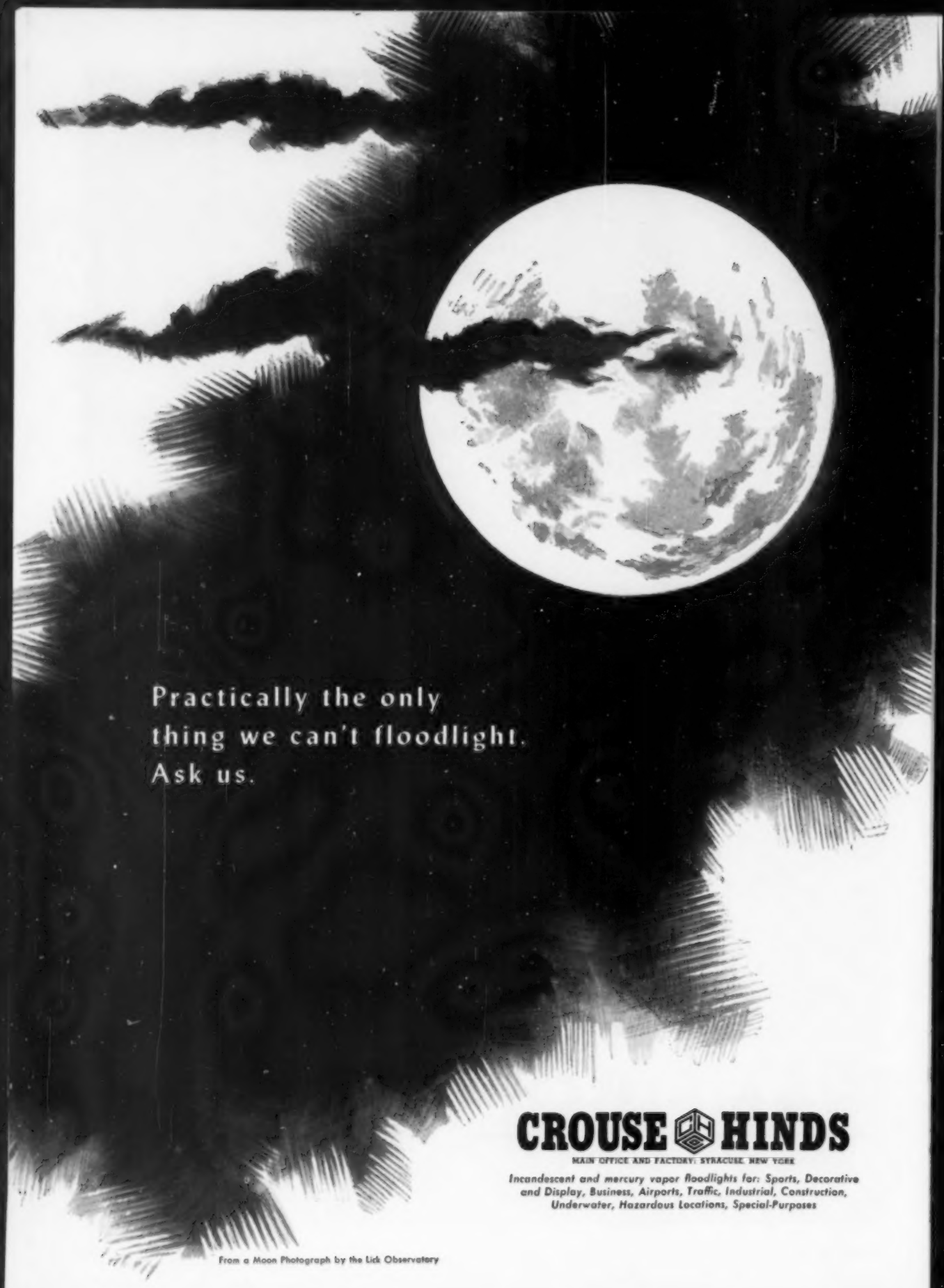
CATALOG NUMBER BF-146

Thin shell concrete structures call for new ideas in interior lighting. This "beehive" structure has been successfully lighted by means of 34 wall urn fixtures each having a 1000 Watt color-corrected mercury lamp. There is a Rambusch Field Representative near you and he is anxious to serve you.

RAMBUSCH

DESIGNERS • MANUFACTURERS

40 WEST 13th STREET • NEW YORK 11, N. Y.



CROUSE HINDS

MAIN OFFICE AND FACTORY: SYRACUSE, NEW YORK

Incandescent and mercury vapor floodlights for: Sports, Decorative and Display, Business, Airports, Traffic, Industrial, Construction, Underwater, Hazardous Locations, Special-Purposes

From a Moon Photograph by the Lick Observatory

ROTUBA'S LIGHTING DATA REPORT 12-58

LIGHTING OF ROCKEFELLER CENTER STORE WINDOWS

LIGHTING OBJECTIVE: To improve the lighting of the display windows by replacing the old luminous plastic material of the double-track ceiling with a more efficient construction plus a more dimensionally stable plastic material for A) uniform, glareless light, B) easier maintenance and C) more attractive general appearance.

These double display windows of Parker & Battersby Men's Camera and Cutlery Store face the interior main floor lobby of the RCA Building of Rockefeller Center, New York.

Major advantages of the Extru-Lite Installation — no glare, uniform light distribution, easy maintenance. Notice how clearly name of store stands out on plate.

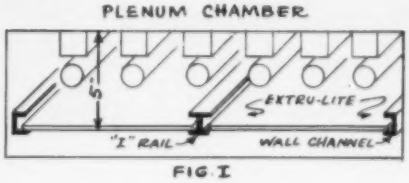


FIG. I

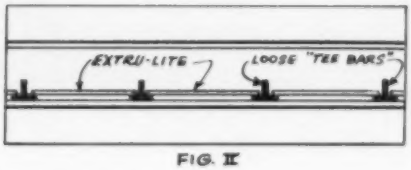


FIG. II

GENERAL INFORMATION: The store owner first realized with a shock that his lighting was deficient, when he could barely distinguish his name on the bronze plaque at window base. This made him aware that his merchandise, too, was poorly illuminated.

Since these windows require a high degree of visibility for the successful merchandising of all the highly detailed items therein, he knew his light shielding was antiquated.

The old ceiling was difficult to remove and infrequently cleaned and the collected dust and grime reduced the illumination even more. The new ceiling was designed so panel components fit snugly, yet could be easily removed for maintenance.

INSTALLATION: Certain parts of the former structure had to be retained; such as, the shallow (abt. 5" deep) plenum chamber, the number of lamps, front and back Wall Channels and the Central "I" Beam (See Fig. 1). Free "Tee" Bars were placed resting on the Wall Channel and reaching across to rest on the Central "I" Beam. (See Fig. 2).

In each "Tee" Bar partition thus formed, sheet of EXTRU-LITE®*, plastic prismatic low-brightness panels cut to size were placed in a regular pattern, with the smooth side of the Extru-Lite facing the lamps. As each "Tee" Bar was inserted, a panel of Extru-Lite was manipulated into place, fitting tightly enough to avoid any dislodgement or slippage.

RESULT: An increase in illumination by approximately 72% — without glare. The Acrylic Extru-Lite (in this installation made of Plexiglas®†) assures greater permanence of color, dimensional stability and eliminates warpage. Nor does Extru-Lite change the true color of light. This fact results in good color quality on the merchandise, showing it up to better advantage. The eye-appealing attention achieved through the increased, superior illumination results in increased traffic for the store.

***That's why we say:* THE BEST BUY IN SIGHT — FIXTURES USING EXTRU-LITE.**

*Available in both Polystyrene or Acrylic.
† Rohm-Haas

RIGID PLASTIC EXTRUSIONS

THE ROTUBA EXTRUDERS, INC.
A DIVISION OF WALJOHN PLASTICS, Inc.
MAKERS OF PLASTIC EXTRUSIONS FOR INDUSTRY
437 88th STREET, BROOKLYN 9, NEW YORK • SHORE ROAD 8-5458

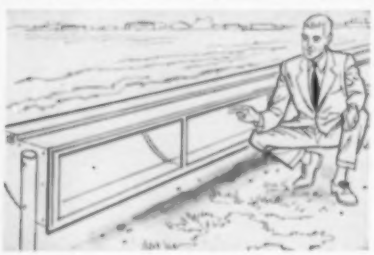
Lighting Equipment designed by Herbert Hoffman, Lighting Consultant, and installed by Condi-Lite Corporation, both of 889-891 Broadway, New York 3, N. Y.

The Sylvania CFR system brings to airports a greater degree of illumination that reflects the pattern of runway white paint markings . . . brings out texture irregularities in runway surface . . . aids pilots in depth perception as well as guidance on landing speed and angle of approach

Before the Sylvania CFR lighting system, "black holes" existed between incandescent beacon-type lights that still line many airport runways

Washington National Airport... spreads a carpet of light with Sylvania CFR lighting system

A newly developed Sylvania lighting system for runways enables planes to land more quickly and safely regardless of visibility conditions. This major advance toward all-aircraft, all-weather operations is particularly important because today's larger, faster planes use more of a runway's length than earlier planes.



Developed co-operatively with the FAA, this new system provides a continuous, broad ribbon of light across the entire width of the runway. At Washington National Airport's instrument runway 36, each 200-watt Sylvania VHO (Very High Output) fluorescent lamp in an 8-foot CFR (Controlled Fluorescent Reflectance) fixture produces a light output of 13,250 lumens. This is possible because Sylvania VHO lamps deliver more than 2½ times the light of ordinary fluorescent tubes.

136 VHO lamps are installed in CFR fixtures along each side of the runway, for a continuous 1400-foot path of light broken only by an intersecting taxiway. The complete installation produces about 3.25 million lumens of light!

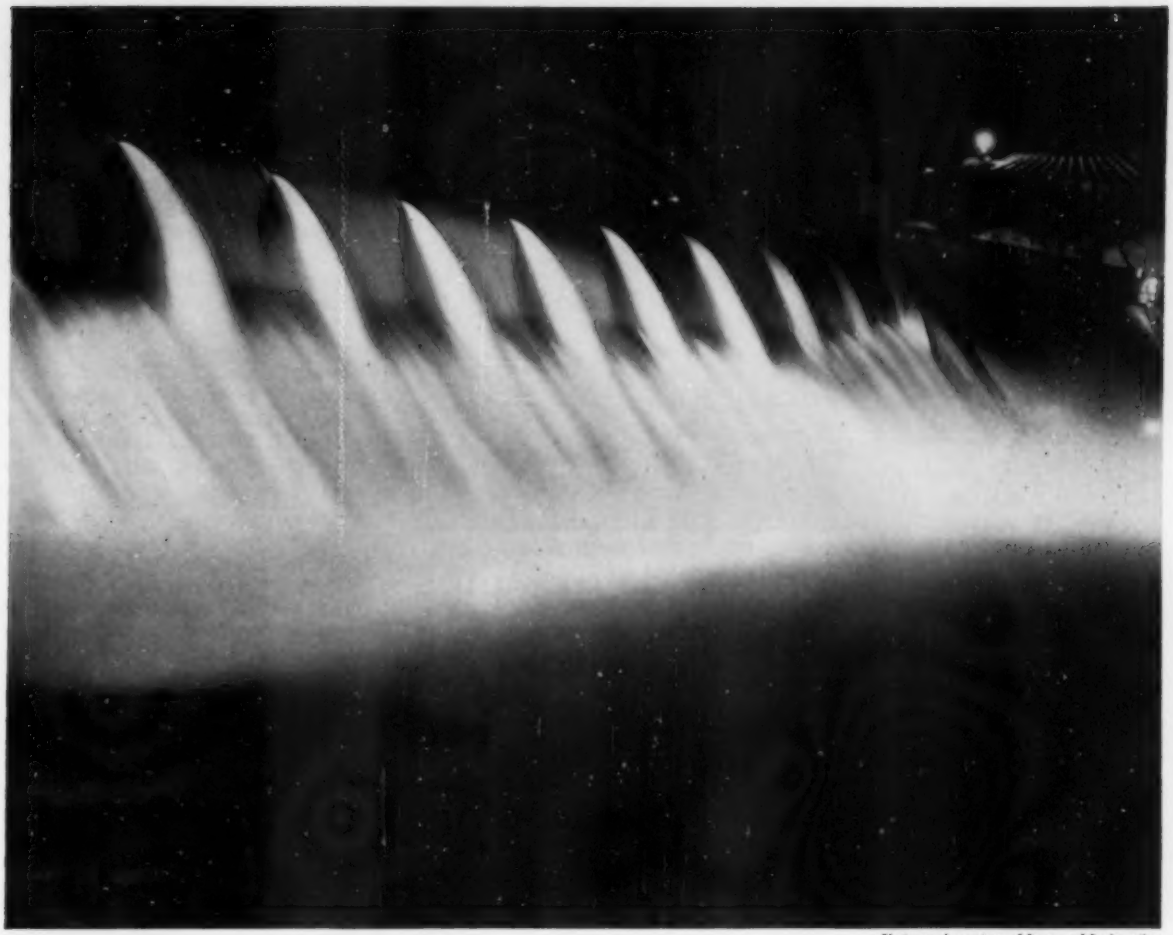
A revealing test for this new lighting system came during early-morning, near zero-zero visibility conditions when incoming pilots reported "little glare, good runway texture and good height guidance" from the VHO runway strip lights.

For full information on new Sylvania VHO lamps and the CFR system—and how they can provide superior lighting at lower cost—call your Sylvania representative, or write:

SYLVANIA LIGHTING PRODUCTS
Division of SYLVANIA ELECTRIC PRODUCTS INC.
Dept. 9L-3503, 60 Boston St., Salem, Mass.
In Canada: Sylvania Electric (Canada) Ltd.
P. O. Box 1190, Station "O", Montreal 9

SYLVANIA ... *fastest growing name in sight*

LIGHTING • TELEVISION • RADIO • PHOTOGRAPHY • ATOMIC ENERGY • CHEMISTRY-METALLURGY



Photograph courtesy of Bureau of Reclamation

PUTTING COLOR IN THE "FLOODS"
AT GRAND COULEE DAM

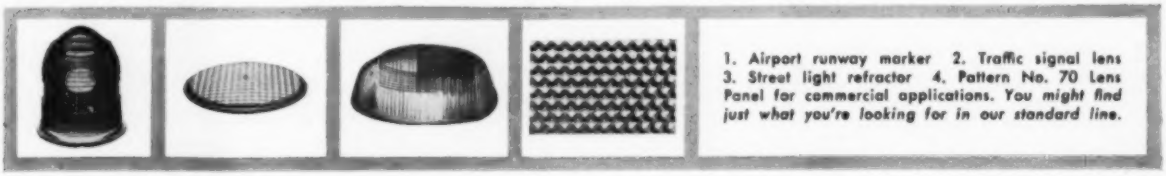
Here's your *problem*: Bathe the Grand Coulee Dam in a rainbow of colors. But keep in mind that *no fragile material will do* because there's *heat* from the high-powered floodlights, *cold* water spray, and the wearing effects of year-round *weather*.

The solution? PYREX brand heat-resistant colored cover glasses from Corning, 686 in total. Each weighs 7 pounds and measures 18 inches across. There are reds, greens, yellows, and a *special* blue developed to produce white when added to red and green. This *special* blue was just another of Corning's many contributions to the lighting industry.

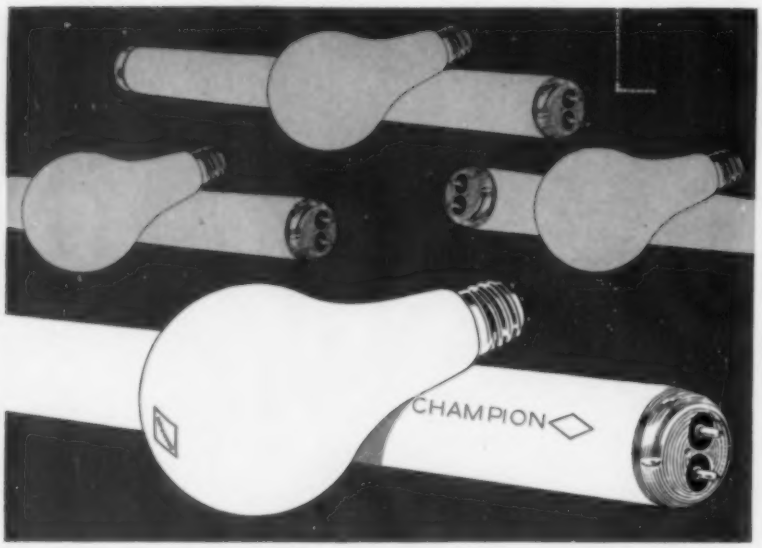
Suggestion: Whatever your lighting need—color correction, direction and control, protection, decoration—you're invited to make use of Corning research and production facilities.

A note outlining your wants will bring a quick answer. Write to Corning Glass Works, 61 Crystal St., Corning, New York.

CORNING GLASS WORKS
CORNING MEANS RESEARCH IN GLASS



1. Airport runway marker 2. Traffic signal lens 3. Street light refractor 4. Pattern No. 70 Lens Panel for commercial applications. You might find just what you're looking for in our standard line.



of the four major brands of lamps

CHAMPION

stands out for

VALUE

Champion balances

- LAMP EFFICIENCY
- LAMP COST
- LAMP LIFE
- LUMEN MAINTENANCE

to give you the most value in

- POWER COST
- LABOR COST
- LAMP COST

which means

- THE MOST LIGHT FOR YOUR MONEY

It's the overall cost of light that counts when you're judging value in lamps.

When you buy Champion Lamps, you're buying lowest overall lighting cost because Champion scientifically determines the balance of lamp characteristics that gives the most light for combined power cost, labor cost and lamp cost.

It's because of this balance that, of the four major brands of lamps, Champion stands out for value.

CHAMPION LAMP WORKS
Lynn, Massachusetts

CHAMPION Lamps
Incandescent Fluorescent
Your best buy in lamps

(Continued from page 31A)

Emmett J. Fallon, Jr. who moves up from the position of advertising and sales promotion manager.

IES Council at its February 12th meeting unanimously approved the recommendation of the Board of Examiners that **Raymond C. Kinney** and **Charles E. Weitz,** now retired, be made Members Emeritus in recognition of their decades of service to the Society during their careers in lighting.

The Edwin F. Guth Co., St. Louis, Mo. has named **Fred MacRae** as their new lighting representative for southern Ohio, Kentucky and southwestern West Virginia. Mr. MacRae, Chairman of the Ohio Valley Section of IES, replaces **Tom Marshall** who recently moved to Florida.

At a special meeting in Boston on February 11, the share owners of Sylvania Electric Products, Inc. voted approval of the merger of Sylvania into the General Telephone Corp. Concurrently in New York, General Telephone share owners also approved the merger. The new corporate name, approved by both groups of stockholders is General Telephone & Electronics Corp. **Donald C. Power,** General Telephone President, will be Chairman of the Board and chief executive officer of the new company, and **Don G. Mitchell** will serve as President. Sylvania will continue its operations as a separate company, wholly-owned by General Telephone & Electronics Corp.

Deaths

Milo A. Briggs, Western Michigan Section.
Harold P. Earley, Western Michigan Section.
B. J. Martin, Chicago Section
Robert A. Miller, Pittsburgh Section.
Charles E. Strecker, Chicago Section.

NEW MEMBERS

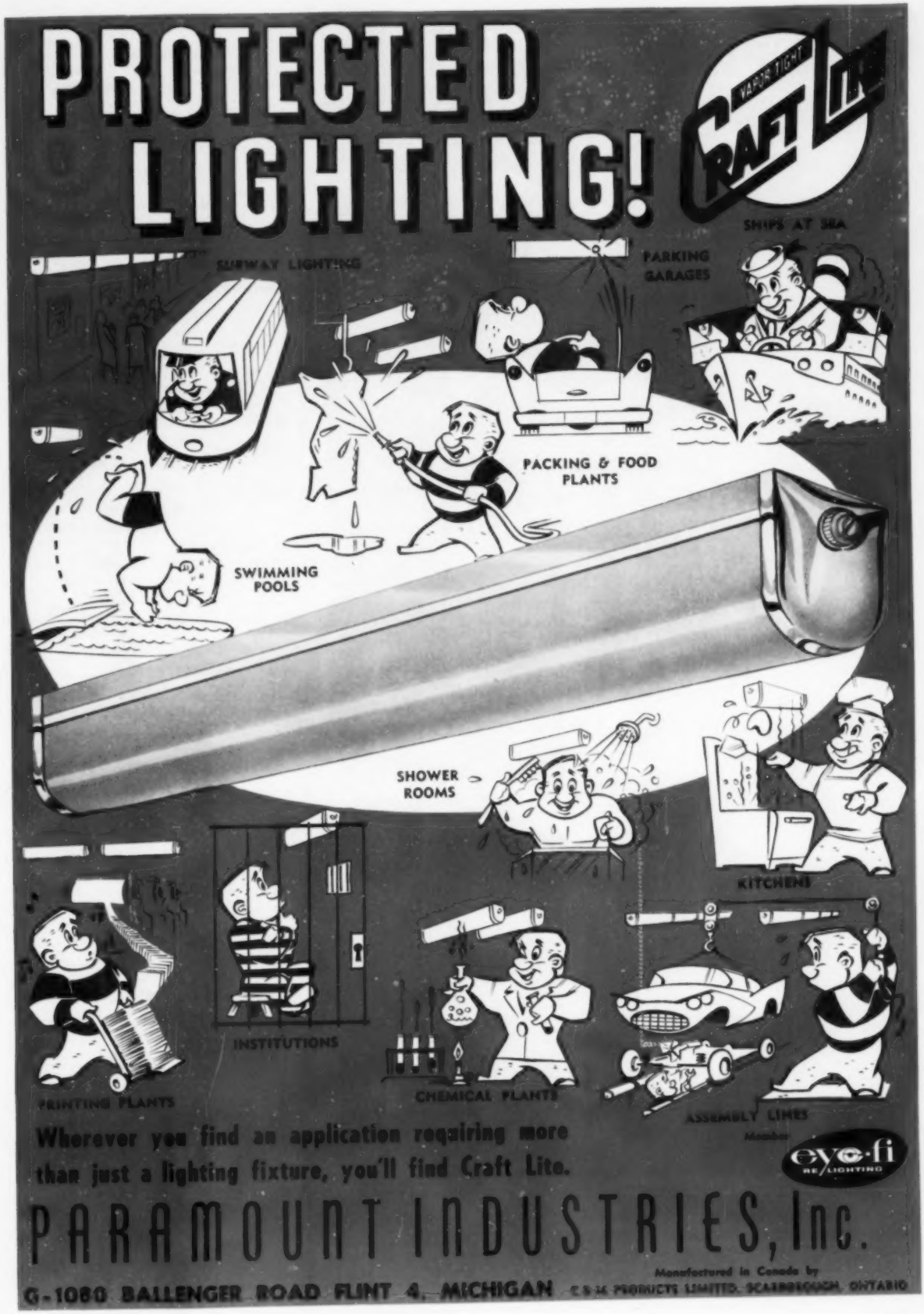
At the meeting of the I.E.S. Council on February 12, 1959, the following were elected to membership. Names marked * are transfers from Associate Member Grade. Names marked ** are transfers from Student Member Grade.

ALABAMA SECTION

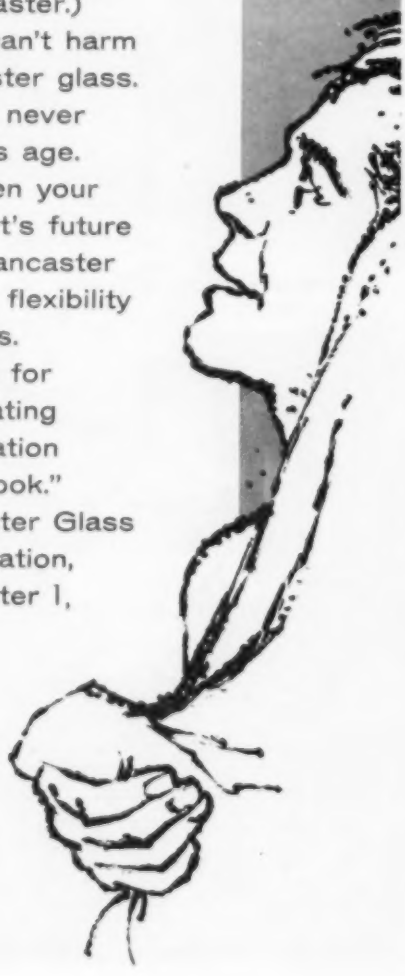
Associate Member:

Jackson, D. M., Alabama Power Co., Birmingham, Ala.

(Continued on page 54A)


PROTECTED LIGHTING!
VAPOR TIGHT
CRAFT LITE
SUBWAY LIGHTING
PARKING GARAGES
SHIPS AT SEA
PACKING & FOOD PLANTS
SWIMMING POOLS
SHOWER ROOMS
KITCHENS
INSTITUTIONS
PRINTING PLANTS
CHEMICAL PLANTS
ASSEMBLY LINES
Member
eye-fi
RE/LIGHTING
Wherever you find an application requiring more than just a lighting fixture, you'll find Craft Lite.
PARAMOUNT INDUSTRIES, Inc.
Manufactured in Canada by
G-1080 BALLENGER ROAD FLINT 4, MICHIGAN
C & M PRODUCTS LIMITED, SCARBOROUGH, ONTARIO

Glass just naturally glows with light. Case in point: This new bathroom ventilator-lamp by Berns Air-King with **Lancaster** diffuser lenses. (Looks smarter, sells faster.) Heat can't harm Lancaster glass. And it never tells its age. Brighten your product's future with Lancaster design flexibility in glass. **Write** for illuminating "Application Handbook." Lancaster Glass Corporation, Lancaster 1, Ohio.



(Continued from page 52A)

ARKANSAS CHAPTER

Associate Member:

Lane, E. J., Gregory Salisbury Co., Pine Bluff, Ark.

ARK-LA-TEX CHAPTER

Members:

*Elkins, I. E., Southwestern Electric Power Co., Marshall, Texas.
*Jackson, R. C., Cahn Electric Co. Inc., Shreveport, La.
*Mack, D. M., Southwestern Electric Power Co., Marshall, Texas.
*Stone, G. W., Southwestern Electric Power Co., Mt. Pleasant, Texas.

BRITISH COLUMBIA SECTION

Associate Members:

Bamford, K. L., Canadian General Electric Co., Ltd., Vancouver, B. C.
Cave, H. L., Cave Electric, Vancouver, B. C.
Haselsteiner, Karl, Foundation of Canada Engineering Corp., Richmond, B. C.
McCarrell, E. D., Canadian General Electric Co., Ltd., Vancouver, B. C.

CAPITAL SECTION

Associate Members:

Kamstra, T. A., Williams, Coile & Blanchard, Washington, D. C.
Lehman, W. C., 1601 Argonne Place, Washington, D. C.
Troth, R. L., U. S. Government G.S.A., P.B.S. Lighting Branch, Washington, D. C.

CENTRAL NEW YORK SECTION

Associate Member:

Lillich, J. E., Corning Glass Works, Corning, N. Y.

CHICAGO SECTION

Member:

Coakley, Rose, Thomas Industries Inc., Louisville, Ky.

CHINOOK CHAPTER

Associate Members:

Reddekopp, W. J., Simpson, Allsopp & Associates, Calgary, Alta.
Steiner, K. M., 2719 Wolfe St., Calgary, Alta.

CLEVELAND SECTION

Associate Member:

Paddock, R. R., Westinghouse Electric Corp., Cleveland, Ohio.

COASTAL BEND CHAPTER

Associate Member:

Webb, D. L., Plumbing & Electric Co., Inc., Sinton, Texas.

CORNHUSKER CHAPTER

Associate Members:

Jacobsen, R. C., Henningson, Durham & Richardson, Omaha, Nebr.
Werp, C. J., Leo A. Daly Co., Omaha, Nebr.

EASTERN PENNSYLVANIA SECTION

Associate Members:

Benatan, Jack, Jewel Electric Products Inc., Harrisburg, Pa.
Boyer, R. F., Wheeler-Fullerton Lighting Division, New Cumberland, Pa.

FLORIDA SECTION

Members:

*Fanus, H. W., Florida Power & Light Co., Daytona Beach, Fla.
*Folsom, A. T., Forida Power & Light Co., Daytona Beach, Fla.
*LaTour, John, Jr., Economy Electric Co., Daytona Beach, Fla.
*Saussy, Hugh, Progress Mfg. Co., Orlando, Fla.
*Schad, R. L., 3124 Corrine Drive, Orlando, Fla.
Stuhl, L. A., Lee A. Stuhl & Associates, Orlando, Fla.
Tyler, Russell, Tyler Electric Supply Co., Daytona Beach, Fla.

Associate Member:

Barnhart, J. F., Barnhart Bros., Daytona Beach, Fla.

FOREIGN NON-SECTION

Member:

Hamilton, W. R., General Electric Cubana, S.A., Habana, Cuba.

Associate Member:

Jacir, S. E. B., Oficina Tecnica De Ingenieria Electrica C. A., Caracas, Venezuela.

GEORGIA SECTION

Associate Member:

Martin, D. C., Thompson Wilson Co., Atlanta, Ga.

GOLDEN GATE SECTION

Associate Members:

Gregory, V. C., Charles Krieger—Consulting Engineer, San Francisco, Calif.

Kirchamer, R. R., Charles Krieger — Consulting Engineer, San Francisco, Calif.

Knolle, F. C., Day Electric Co. of Marin, Inc., San Rafael, Calif.

Smith, D. H., Tamalpais Electric Co., San Anselmo, Calif.

Student Member:

Peterson, E. H., University of California, Berkeley, Calif.

HEART OF AMERICA SECTION

Associate Members:

Kilz, Hans, Jr., City of Kansas City, Mo., Kansas City, Mo.

Schecher, B. T., Kansas City Power & Light Co., Kansas City, Mo.

Student Members:

Birdsall, R. D., Jr., Finlay Engineering College, Kansas City, Mo.

Carter, J. T., Finlay Engineering College, Kansas City, Mo.

Dalton, P. L., Finlay Engineering College, Kansas City, Mo.

Dillbeck, J. A., Finlay Engineering College, Kansas City, Mo.

Foland, H. E., Finlay Engineering College, Kansas City, Mo.

Hook, R. L., Finlay Engineering College, Kansas City, Mo.

Irwig, F. H., Finlay Engineering College, Kansas City, Mo.

Maxwell, J. J., Finlay Engineering College, Kansas City, Mo.

McMillan, G. J., Finlay Engineering College, Kansas City, Mo.

Rawlings, M. R., Finlay Engineering College, Kansas City, Mo.

Wood, L. A., Finlay Engineering College, Kansas City, Mo.

MICHIGAN SECTION

Member:

Kormendy, L. J., Benedict & Associates, Dearborn, Mich.

Associate Members:

Collier, T. H., Eberle M. Smith Associates, Inc., Detroit, Mich.

Greenfield, Haskell, Greenfield & Kronick, Detroit, Mich.

Hoeffel, T. L., Sarin Electric Co., Detroit, Mich.

Kolon, E. C., Colonial Electric Co., Detroit, Mich.

Laur, W. J., Consumers Power Co., Bay City, Mich.

Rosenberg, Leslie, Rotor Electric Co., Detroit, Mich.

Upleger, W. G., Graybar Electric Co., Detroit, Mich.

MID-SOUTH CHAPTER

Associate Members:

Graves, C. O., Jr., William B. Thompson — Consulting Engineer, Memphis, Tenn.

Kaufman, B. L., Westinghouse Electric Corp., Memphis, Tenn.

Lusk, E. H., Westinghouse Electric Corp., Memphis, Tenn.

MILWAUKEE SECTION

Associate Members:

Flaig, O. J., Electrical Engineering Bureau, Inc., Milwaukee, Wis.

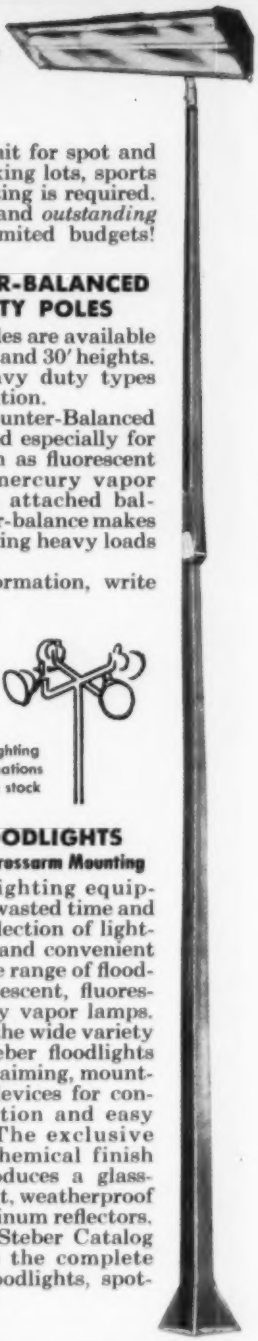
Harryman, Dean, The Miller Co., Hales Corner, Wis.

Wallock, D. W., Electri-Craft, Milwaukee, Wis.

(*Continued on page 56A*)

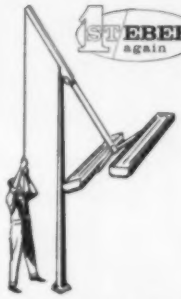
NOW—FOR BIG OUTDOOR LIGHTING JOBS

STEBER has the right Units, Accessories, Prices!

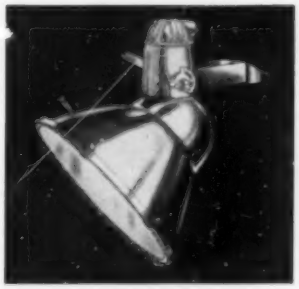


The Steber line offers every popular type of unit for spot and floodlighting loading docks, railway yards, parking lots, sports areas, plazas—anywhere good, economical lighting is required.

When you specify *Steber*, dollars go farther and *outstanding* lighting installations are achieved on even limited budgets!



STEBER FLOODLIGHTS



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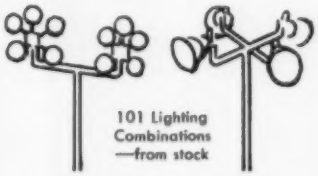

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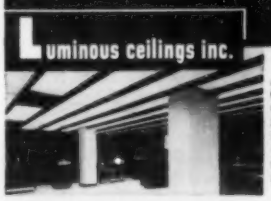

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(Continued from page 57A)

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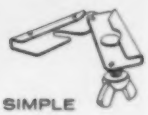

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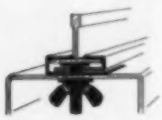

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